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AT

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Bulletin of the Museum of Comparative Zoölogy
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ON URNATELLA GRACILIS.

By C. B. Davenport.

With Six Plates.

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No. 1. — *On Urnatella gracilis.* By C. B. Davenport.[1]

Contents.

I. Introduction.

In November, 1851, the late Dr. Leidy published, in the Proceedings of the Academy of Natural Sciences of Philadelphia, a notice of "what I suspect to be the cœnœcium of a new genus of Polyzoa; although I have never been able to detect the polypides if such exist." He gives three figures of the "cœnœcium," consisting of a series of urn-shaped segments placed so that the base of one segment rests on the mouth of its proximal neighbor. To this new genus he gives the name Urnatella, with a genus diagnosis, which three years later ('54, p. 191), after discovery of the polypide, was revised to read as follows: "Cœnœcium consisting of a series of segments up to eighteen in number, and forming free, semi-erect, curved stems, attached only by the base of the lowest segment. Segments excepting the three last ones simple, urniform; the antepenultimate and the penultimate oblong, with simple or compound branches of the same form; the last segment or active polyp is campanulate, and is supplied with cylindrical, ciliated arms arranged in a circle around the mouth." He finds that several stems arise from a common base. There are fourteen tentacles.

In 1856 Allman (pp. 117–119) referred to the discovery of Leidy, and published a pencil sketch of Urnatella furnished by Leidy. This is the

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXIII.

first published drawing of the calyx and young branches. Allman was inclined to refer this genus to the Pedicellinidæ.

In 1870 Leidy recorded further observations on Urnatella, and in 1884 he published in a thin quarto, with a single plate, everything which he had found out about its anatomy and physiology. The main points of these papers will be brought out in connection with the organs to which they refer.

Finally, Mr. Edward Potts, in a note to one of the editors of the American Naturalist (April, 1891), states that he has succeeded [as did Leidy] in obtaining in the spring rejuvenated heads from the headless stems of Urnatella gathered the preceding fall.

Various writers have called attention to the imperfections in our knowledge of this aberrant form. Ehlers ('90) has made many suggestions concerning the anatomy of Urnatella, which, being purely hypothetical, require to be settled by observation. Leidy himself was impressed with the importance of a better knowledge, and he had intended, he says ('84, p. 6), to make a thorough investigation of it. "Other occupations, and the want of a ready supply of the necessary material, have prevented my intention, and I am now led to communicate what I have learned of the animal with the view that some of my younger countrymen and co-laborers, under more favorable circumstances, may be induced to do what I had hoped and wished to do." To supplement the work of Professor Leidy is the object of the present paper, which has been largely inspired by his.

In 1884 Leidy remarked upon the absence of Urnatella from its former haunts. Apparently nothing had been seen of it since that time, until, in 1889, I opened correspondence with Mr. Edward Potts of Philadelphia upon the subject. In the summer of 1890 Mr. Potts and I thoroughly examined the waters of the Schuylkill River, both above and below the Fairmount dam, but without finding any trace of Urnatella. In September, 1891, Mr. Potts found many stocks in the bed of the temporarily emptied Schuylkill Canal, below Flat Rock dam, and kindly forwarded some of these, living, to me at Cambridge. In July, 1892, Mr. Potts and I re-examined in vain the Schuylkill River at Fairmount dam, and finally, on July 4, made dredgings in the Schuylkill at Flat Rock dam, near Shawmont Station, Pennsylvania. We found no trace of Urnatella in the quiet waters above the dam, but in the turbulent waters immediately below the overflow almost every stone brought from the bottom bore stocks, and some were almost completely covered on one face with luxuriant growths. One barrel-hoop dredged from the mud was

completely covered with headless stems. As many stones as we could carry were packed in moist paper or in jars, and transported safely several miles. A few days later, stones with living stocks of Urnatella and parts of the barrel-hoop with headless stems were transported in a pail of water to Cambridge. Upon arrival at Cambridge it was found that nearly all the heads had dropped off. The stocks were kept in running water for three months, during which time those which had lost their calyces did not regenerate them; whereas the stocks on the barrel-hoop did regenerate their heads, but did not bud very luxuriantly.

I cannot close this introduction without expressing thanks to my friend Mr. Potts, who, filled with love for the science, has unselfishly supplied me with material, hospitably received me into his household during my stay in Pennsylvania, and worked with me beyond his strength in our dredging operations on the Schuylkill in order to further a study of this animal.

The later studies included in this paper were made in the Embryological Laboratory, under the direction of Dr. E. L. Mark. .

I propose to describe first the anatomy of the adult, and, in the second place, the non-sexual reproduction and regeneration, so far as I have been able to determine them. In each section of the paper I shall give first my own observations on Urnatella; secondly, compare them with those of others on Urnatella or other Endoprocta; and, finally, give my conclusions upon or interpretation of any difficult points.

II. Anatomy.

For the purposes of description we must distinguish the stalk and the calyx.

1. *The Stalk.*

The stalk is an elongated, filamentous structure, composed of a number of segments, lying one beyond the other. The number of such segments varies from one to several, according to the age of the stalk. Leidy counted as many as eighteen. I have never counted more. Looked at with a hand lens, the stem is seen to be composed of alternating translucent and opaque rings, of which the former occupy the middle zone of each segment; the latter have an intersegmental position. The surface of the stalk in the translucent zone is thrown into circular folds, and small processes appear scattered over its surface, more abundantly on the more distal segments (Plate I. Fig. 6).

An optical longitudinal section of the living stalk (Plate I. Fig. 7) shows that it consists of a thick cuticula, within which is a mass of ill-defined tissue. The cuticula is thicker and more opaque in the basal segments, thinner and more transparent in the distal ones. Each of the basal segments often contains a mass of globular, highly refractive bodies, which may be forced out from the segment by crushing the latter (Plate I. Figs. 4, 5). Isolated by this means they are seen to be of the most varied size, and to resemble yolk spherules. Besides these granules, one finds lying near the cuticula in all but the oldest segments a fibrillated layer consisting of elongated, spindle-shaped, highly granular cells in the midst of the yolk spherules (Plate I. Fig. 7), and, finally, one or several flickering bodies reminding one by their motion of the *cirri*[1] of flame cells. In the dark zones optical sections reveal indications of a transverse septum.

A more accurate insight into the histological structures is gained from thin sections of the stalk.

The *cuticula* appears in two conditions, which are not sharply separated, but pass into each other through intermediate conditions. The one kind (Plate I. Fig. 4, *cta.*) occurs in the middle zone of each segment. It is transparent and flexible, and becomes thicker in passing from the distal to the proximal segments. It stains in hæmatoxylin, and is then seen to be composed of laminæ, for it appears in section distinctly striated (Plate I. Fig. 4 ; Plate II. Fig. 16). The other kind of cuticula occurs chiefly at the constrictions between segments, but it extends over the two ends of the segments also, and even over the middle zones of the segments, as an outer cuticula (Plate II. Fig. 8, *cta'.*). It forms, moreover, the septa between adjacent segments. It does not stain in hæmatoxylin, is more highly refractive than the first kind, and has a yellowish color by transmitted light. Where it passes over into the first mentioned kind of cuticula, it becomes distinctly striated, and gradually loses its specific characters, gaining those of the first kind, of which it is probably only a modification. It is the presence of these two kinds of cuticula that causes the superficial appearance of alternating light and dark zones on the stem. These two kinds of cuticula do not correspond to the inner and outer cuticulas which Ehlers ('90, pp. 16, 17) describes for Ascopodaria. Two layers with the characters of those of Ehlers appear not to exist in Urnatella.

The *ectoderm* (Plate II. Figs. 11, 10, 16) diminishes in thickness from

[1] I employ the word "cirrus" in the sense in which it is used by Butschli for Ciliata (cf. Bronn's Thierreich, Protozoa, p. 1324).

the distal end of the stalk, where it is a layer of cuboidal cells, to the base, where its cells are extremely flattened, so that the layer is hardly distinguishable. Even near the base of the stalk, however, the ectoderm is a relatively thick layer on each of the surfaces of the transverse septa.

The *axial portion* of the stalk presents very interesting histological conditions. In a young individual whose stalk comprises a single segment only (Plate II. Fig. 15) the axial portion contains a closely packed mass of cells, which stain deeply, contain few vacuoles, and are slightly elongated in the direction of the axis of the stalk. At a later stage one finds the plasma of some of these cells undergoing a metamorphosis. Such cells appear filled by a vacuole in which lie numerous highly refractive granules. A little later all of the axial cells have become greatly elongated in correspondence with the elongation of the stalk. Many of them appear almost completely vacuolated. A cross section of the stalk at such a stage of development is shown in Plate II. Figure 9, where the centre is filled with a network of cell boundaries enclosing clear spaces. This condition is very striking in longitudinal sections through the region of the septum, where the long vacuolated cells may be seen extending from one segment into the other.

According to Ehlers ('90, pp. 18–22), the stolon of Ascopodaria shows a condition of the axial portion similar to that here described; but in the stalks which support the calyces there is a considerable amount of intercellular substance, and I find the same thing in Pedicellina. In Urnatella, on the contrary, such intercellular substance appears only in the older stalks.

The *musculature* of the adult stalk is situated immediately within the ectoderm, and is found in all segments running from one septum to the other. On cross section of the stalk it appears as a circle of radially elongated, highly refractive bodies, placed close to the ectoderm (Plate II. Fig. 9, *mu*). Each elongated body has, at a certain focus, a darker periphery and a lighter central line. With the highest powers the darker periphery can be resolved into a single row of bodies, which appear as bright spots at the highest, as dark spots at the lowest focus (Plate II. Fig. 16, *mu*). These I interpret as fibrillæ.

The fibrillæ develop in the protoplasm of the axial cells. In their earliest stages one sees them forming a single row on the outer edges of the more peripheral cells (Plate II. Fig. 17, *mu*). Later they are formed on the two lateral edges also (Fig. 11). Additional lateral (or, in relation to the stalk, radial) rows of fibrillæ are next formed in each cell, the new rows appearing nearer the centre of the cell than those already

formed (Fig. 10). Finally, in the adult, the nucleus of the cell, which has been pushed centripetad by the multiplication of fibrillæ, comes to lie opposite several pairs of radial rows or sheets of fibrillæ. These sheets always occur in pairs, the components of the pairs being separated by a narrow clear space, and the pairs by broader spaces.

As I have said, this musculature occurs throughout the entire stalk up to the base of the calyx (Plate III. Fig. 19, *mu.*). I do not understand on what ground Ehlers states ('90, p. 146) that in Urnatella "der Muskelmantel in den gleichmässig dicken Stengelgliedern nicht deren ganze Länge erfüllt."

There is a considerable difference between my description of the structures of the muscle fibres and that of Ehlers ('90, pp. 25–28) for Ascopodaria. In the latter case, the muscle cells are placed three to five deep, instead of in one peripheral series, as in Urnatella. Moreover, in Ascopodaria the fibrillæ lie in two thick peripheral bands on the sides of each muscle cell; whereas in Urnatella several muscle bands (each consisting of a single row of fibrillæ) belong to each cell.

The differences between the two genera are easily explained by assuming an increase in the number of muscle cells in Ascopodaria, so that they can no longer lie in a single peripheral series, and the fibrillæ bands have become greatly crowded together, so that one band is not equivalent to a single band of Urnatella, but to all of the bands of Urnatella which have arisen on one side of the cell. The stalk musculature of Ascopodaria is thus more highly developed than that of Urnatella.

Ehlers mentions the resemblance between the muscle fibres of Ascopodaria and those of Nematodes, especially the Cœlomyaria.

I have referred above to vibratile movements in the living stalk. Stained sections show, placed more or less abundantly throughout the stalk, elongated spaces terminating blindly at one end in structures which must be regarded as flame cells (Plate II. Fig. 12, *cl. flm.*). Such a flame cell is spherical in form, stains slightly, possesses a large nucleus, and gives off into the elongated space *cl. tb.* the well known cirrus (*Wimperflamme*).

The form of the cirrus in all cases examined was conical, the axis of the cone being usually thrown into a sigmoid curve. Where the cirrus arises from the cell, it is slightly constricted, then enlarges suddenly, forming a thickened ring. Distal of this ring the cirrus tapers gradually to a fine point. That the cirrus is composed of a number of agglutinated cilia is indicated by the presence of longitudinal striæ. I believe that the flame cell closes the lumen of the tubule at this point.

Concerning the space into which the free end of the cirrus projects I can only conclude, from comparison with other cases where a flame cell occurs, that this must represent the lumen of an excretory tubule. I have not, however, been able in any instance to trace an individual tubule to any considerable distance, or until it opens into any other organ. One thing seems fairly certain, there is no morphological difference between those elongated clear spaces into which the cirri project and the elongated vacuolated cells to which reference has already been made. I am therefore inclined to regard it as probable that they are one and the same thing. The vacuolated cells are developed by the breaking down of the plasma of the elongated cells of the young stalk. Before the metamorphosis is completed, one finds cells filled with clear contents, in which lie scattered granules (Plate II. Fig. 15, *cl. tb.* left). Finally, even these seem to disappear (Fig. 15, *cl. tb.* right). Since the tubules agree in size with these elongated, later vacuolated cells, I conclude that their lumina are intracellular. Since the so called vacuolated cells — many of which at least are, according to my view, tubules — pass uninterruptedly from one segment to the next through the centr[illegible]pening of the septa, there may easily exist continuous tubules [illegible]ıg from the basal segments into the calyx.

The only [illegible]xcretory tubules which have been heretofore mentioned as occurring in Endoprocta are the pair which lie in the calyx and open into the atrium between mouth and rectum. Farther on, I shall have occasion to inquire into the probable significance of the facts here recorded.

In specimens of Urnatella gathered in the fall and examined while living, I found the basal segments filled with yolk granules (Plate I. Fig. 4). Even in stocks collected in July, the basal segments contained a greater or less amount of yolk. In passing from the distal towards the proximal end of the stalk, one can trace the development of this yolk, and since this is a matter of some general interest I have paid a little attention to it.

If we examine one of the middle segments of a stem whose basal segment is full of large yolk spherules, we shall find reserve stuff forming in some of the elongated cells. It appears as a fine granulation throughout the whole cell, except immediately surrounding the nucleus (Plate II. Fig. 13). Not all of the cells appear thus granular, for others are at this stage vacuolated. Still later (Fig. 14) many of the fine granules appear to have fused into larger ones, and these are separated by clear spaces. The cells have enlarged very greatly (those

in Figs. 13 and 14 being equally magnified), and their boundaries seem to be at some points discontinuous. Finally, in the basal segment we find all trace of cell boundaries lost, and the central space filled by a mass of large and small yolk globules, nuclei, and protoplasmic débris (Plate II. Fig. 8).

The series of stages in the formation of yolk, which are shown in successive segments of the same stalk, points to the conclusion that yolk is in this case formed inside of the cell by a fusion of many excessively small granules, — a conclusion similar to that reached by Stuhlmann ('87, p. 23) for the eggs of a Teleost. Hand in hand with the development of yolk there seems to go a diminution in the amount of protoplasm, which therefore seems to be broken down in the process. The details of this process resemble remarkably those of the formation of the yolk in the statoblast of Phylactolæma, for an accurate description of which we are especially indebted to Braem ('90, p. 76).

Urnatella is quite unique, so far as I know, among all Endoprocta in the storage of food material in its stalk. This is doubtless of high physiological importance, as I shall try to show later.

Septa occur at the constrictions between segments, and separate the latter from one another. They are composed of a circular fold of ectoderm, whose free edge surrounds a small opening, through which spindle-shaped vacuolated mesenchymatous cells pass. The adult condition is easily interpreted by reference to the development, an early stage in which is shown in Figure 24 (Plate IV.). Between the layers of the ectodermal fold a perforated disc of cuticula — continuous at its outer edge with the superficial cuticula — becomes laid down. This cuticular disc increases in thickness with increasing age.

The most distal septum, which separates stalk and calyx, is more complicated than the others. The complication is due to the fact that mesenchymatous cells have placed themselves in and above the opening of the septum, and have flattened themselves out perpendicularly to the axis of the stalk, while still allowing the vacuolated cells to pass at their margins into the calyx from the stalk. Thus the transversely flattened mesenchymatous cells appear to send out horizontal processes between the tubular cells (Plate IV. Fig. 25).

The flattened cells which lie above the opening of the septum are seen, in longitudinal section of the stalk, to be arched over the opening. It results from this that the smaller, lower cells lie partly enclosed by the larger upper ones (Plate III. Fig. 18).

A septum between stalk and calyx agreeing even in detail with that

just described for Urnatella has been described and figured by Ehlers for Ascopodaria. Such a highly complicated septum seems indeed to be common to the Pedicellinidæ, which in this respect appear more nearly allied to Urnatella than does Loxosoma, in which such septa are absent.

In Pedicellina Benedeni also, which has a segmented stalk, the segments are separated from one another, according to Fœttinger ('87, pp. 301–303), by perforated septa.

2. *The Calyx.*

Under this heading I shall treat successively of the body wall (including the lip of the atrium, and the tentacles), the atrium, the alimentary tract, the body cavity, the nephridia, the sexual organs, and the nervous system.

A good idea of the external form of the expanded calyx may be gained from Leidy's figures. My own, having been drawn chiefly from preserved material, show the polypide for the most part in a retracted condition (cf. Plate I. Fig. 2). When thus retracted, the atrial opening does not lie at the apex of the calyx, but is thrown sharply over towards the oral aspect (Plate III. Fig 18).

The body wall is composed of a single layer of excessively thin epithelium, — the ectoderm, — which has secreted a thin cuticula. This cuticula is thickened in places, producing papillæ, which are irregularly scattered over the calyx. At the lip of the atrial opening, as the passage into the atrium in the retracted condition may be called, the ectoderm is thicker than elsewhere, and folds back upon itself until it reaches the base of the lophophore. This backward-reflected portion I shall call by the name *kamptoderm*, for although its homology with the kamptoderm of Ectoprocta may not be entirely beyond doubt, I cannot see any important difference between the two structures, either in their adult relations or in development. As in the Ectoprocta, so here the polypide is formed in the retracted state, and the atrial opening does not break through until a late stage is reached.

In Ectoprocta the line of union of the kamptoderm and body wall, i. e. the lip of the atrial opening, is marked by a thickened ring composed of elongated ectodermal cells, at the base of which lie the fibres of a sphincter muscle. This organ constitutes the "Randwulst" of Phylactolæmata or the "Diaphragma" of Gymnolæmata. Does an organ homologous with this occur in Urnatella? It is in keeping with the more primitive organization of the Endoprocta that, although a corre-

sponding region exists and sphincter muscles are found here, it has not become so distinctly differentiated from the rest of the body wall as has the *Randwulst* of Phylactolæmata. This region may be designated the lip of the atrium.

When the tentacles are expanded, — a secondary condition, as the development of the calyx shows, — the lip of the atrium forms a circular ridge lying at the base of the tentacles (Plate IV. Fig. 26, *sphi. atr.*). When the tentacles are drawn in tightly, the lip of the atrium becomes puckered. Two of the folds resulting from this process are shown cut across in Figure 19 (Plate III.) above the middle of the atrium.

The *tentacles* of Urnatella in three cases in which I counted them on transverse sections, as well as on the entire animal, numbered twelve; in one case, thirteen. In addition to these numbers, Leidy ('84, p. 10) found sixteen (usually) and fourteen. In the specimen with thirteen tentacles, the odd one was placed on the anal aspect of the calyx in the median plane. It appeared shorter than the others. In one case with twelve tentacles, observed fully expanded, the two tentacles of the anal aspect lying nearest the median plane appeared shorter than the remaining ones. Leidy does not refer to this point, and his figures afford no satisfactory evidence as to the occurrence of this condition in his specimens.

The tentacles are each composed of a cylinder of columnar epithelium surrounding a narrow central region which is filled with mesenchymatous tissue. In addition, on each of the lateral aspects of the tentacle there is a muscle, composed of one to three fibres lying side by side (Plate IV. Fig. 27, *mu. ret. ta.*). The epithelium is ciliated on the lateral and inner faces of the tentacle.

The *atrium* is bounded by the tentacular corona on all sides. The floor of the atrium passes into the mouth in the oral region, and rests upon the rectum in the aboral region. At the centre there opens into it an elongated pocket, the cloaca. The lateral angles of the mouth are prolonged aborally, and form two grooves which open into the atrium along the lateral margins of the floor (Plate III. Fig. 19, *sul. atr.*). These, which may be called the *atrial grooves*, approach each other and become shallower as they pass aborally upon the atrial wall, until they disappear in the median line above the rectum. The epithelium lining the grooves is ciliated.

This "atrial groove" exists also in Pedicellina echinata according to Nitsche ('69, pp. 21, 22), and, according to Ehlers ('90, pp. 52, 53, 59, 60), in his Ascopodaria macropus also. Its function, as has been fre-

quently pointed out, must be to carry the particles of food from the bases of the tentacles towards the mouth.

The mouth is limited on the side towards the anus, and separated from the cloaca by a fold, which may be designated the *inner lip*. This represents the organ often referred to as the epistome, — a term which implies an homology with the organ of the same name in Phylactolæmata. This organ is of greatest size in Rhabdopleura and Loxosoma among Endoprocta, where it is elevated far above the general level of the floor of the atrium. It is less marked in the Pedicellinidæ. In Urnatella it is not at all evident, because its upper edge is not higher than the roof of the rectum which forms the actual floor of the atrium behind. If, on the contrary, the cloaca extended underneath the rectum, as it does in the Pedicellinidæ, causing a great space between it and the intestine, and thus making the roof of the *intestine* the floor of the atrium, the inner lip would appear as a very prominent organ (cf. Fig. 18).

On the outer edge of the mouth, and forming the "outer lip," is a prominent horizontal fold of the oral part of the atrium (Fig. 18, *loph. atr.*). This fold extends aborally, running parallel with, and forming the outer wall of the "atrial groove" (Fig. 19). The fold gradually becomes less pronounced towards the aboral aspect of the atrium until (in Fig. 18) it forms only a slight swelling of the atrial wall over the rectum.

Alimentary Tract. — As in other Endoprocta, so in Urnatella one can distinguish four regions in the alimentary tract: œsophagus, stomach, intestine, and rectum. The wall of the alimentary tract is composed throughout of a ciliated epithelium, except in the so called hepatic cells of the upper wall of the stomach. In this exception Urnatella agrees with other Pedicellinidæ, but for Loxosoma Harmer makes no such exception.

I find a highly refractive basement membrane lying at the base of the digestive epithelium. This stains deeply in hæmatoxylin, so that it can be seen with a low power as a distinct line surrounding the alimentary tract. Such a condition, described by Nitsche ('69, p. 19) for Pedicellina, has been denied by Ehlers ('90, p. 72) to exist in Ascopodaria.

There is an indication of a specialized intestinal (sphincter) muscle surrounding the opening leading from intestine to rectum, as well as at the anus. The structure in question, which appears in section (Fig. 18, *spht.*) as highly refractive and deeply staining areas on either side of the opening, seems to lie in the epithelial wall of the alimentary tract.

Since elsewhere in the calyx of Urnatella, and in other Bryozoa, muscles arise from mesodermal tissue, I am inclined to believe that, notwithstanding their position, they are formed from mesenchymatous cells which have crowded in between the epithelial cells.

The free surfaces of the epithelial cells are different in the various regions of the alimentary tract. On the wall of the œsophagus they run out into tolerably close-set and long cilia, which become longer towards the deep end of the œsophagus, and project into the stomach at its cardiac end (Fig. 18, *œ.*). Along the lateral and lower sides of the stomach one finds longer sparsely distributed cilia, and at their base a close-set layer of short rods (Stäbchen). Around the pyloric opening of the stomach there is a ring of elongated cilia. The intestinal epithelium bears chiefly short, stout, and close-set *Stäbchen*. The cilia of the rectum are confined to the upper wall, and are of medium length, and sparse. These are omitted in Figure 18.

The position of the mouth has been already defined. It leads into a broad *œsophagus*, constantly narrowing as it descends until it opens into the stomach at the lower (oral) end of the latter. Its wall consists of a columnar epithelium, some of whose cells are vacuolated, especially at the base of the epistome. The inner wall of the œsophageo-gastric opening is provided with a valve-like process, covered, like the opposite wall, with large cilia.

The pear-shaped stomach is lined below and laterally by a cuboidal or short columnar epithelium, above by a highly granular, more or less vacuolated, non-ciliated epithelium, whose free ends are ragged, sending processes into the lumen of the organ. These constitute the so called hepatic cells. Their granules stain deeply in hæmatoxylin. In the epithelium of the lateral and lower walls of the stomach deeply staining cells alternate irregularly with less deeply staining ones (Fig. 18). These cells are also full of small vacuoles.

The stomach is separated from the intestine by a circular ridge, formed of elongated cells bearing long cilia, — the pyloric valve.

The cells of the conical intestine are cuboidal, and possess a thick external and internal membrane, which stains deeply in hæmatoxylin. The passage into the rectum is restricted.

The epithelium of the rectum is composed of flattened cells. Its lower wall is closely applied to the upper wall of the intestine, the two walls being separated by the basement membranes of the two cell layers.

The anus lies, as already stated, on the aboral wall of the cloaca. At this point the wall of the rectum becomes continuous with the floor of

the atrium above and the aboral wall of the cloaca below. The cells surrounding the anal opening are slightly larger than their neighbors. Lying apparently in the basement membrane is the anal sphincter already mentioned.

Under the term *body cavity* I include the space lying between the alimentary tract and the outer body wall and atrium. This space, which is much reduced in the retracted condition of the polypide, contains indifferent mesenchymatous tissue, tubular cells, muscles, the excretory and sexual organs, and the nervous system.

The body cavity is bounded by no other epithelium than the ectoderm of the body wall and atrium, and the entoderm of the alimentary tract; that is to say, there is no mesoderm.

The indifferent mesenchymatous cells have been seen to best advantage in the end of a regenerating stalk shown in Figure 3. Here the cells, which were studied while living, could be seen migrating on the inner surface of the ectoderm, and extending through the central region. Such wandering cells were filled with highly refractive granules.

The tubular cells of the body cavity lie chiefly at the base of the calyx, near its attachment to the stalk. In this region also I have seen in the living animal a flickering ciliate movement, and in the sectioned animal flame cells.

I have been able to distinguish only two systems of muscles in the body cavity of Urnatella, — the sphincter of the atrium, and the muscles of the tentacles.

The sphincter of the atrial opening (Plate III. Fig. 18, Plate IV. Fig. 26, *spht. atr.*) is composed of circular fibres lying in the lip of the atrium. Taken together, the fibres form a folded sheet, U-shaped on cross section, the convexity of the U being directed upwards. The function of this muscle is, of course, to constrict the atrial opening, and thus to protect the tentacles and parts below.

The tentacular muscles consist of the pair to each tentacle already mentioned. These run from the apex of the tentacle to the base, where they diverge to the right and to the left, and, after breaking up into many branches, pass through the ectoderm to become inserted upon the cuticula of the body wall. Leidy ('84, p. 10) saw these tentacular muscles.

Differentiated muscles do not seem to be abundant in the calyx of any of the Endoprocta. Tentacular muscles are unknown in other species. On the other hand, Ehlers ('90, pp. 64, 65) has described two systems for Ascopodaria which I have not seen in Urnatella, namely, lateral

wall muscles and transverse muscles, the latter running from the right to the left wall. The fibres of these muscles also break up into branches before making their attachments.

Excretory Organs. — The chief excretory apparatus in Urnatella lies in the calyx below the ectodermal floor of the atrium (Plate III. Fig. 18, Plate IV. Fig. 22, *nph.*). It consists of a pair of tubules which unite proximally and open by a single pore into an unpaired cavity, which in turn opens into the atrial chamber at about the centre of its floor. This unpaired cavity is the one I have proposed to call the *cloaca.*

From its opening into the cloaca the unpaired tract of the excretory tubules, which may be designated *efferent duct,* runs oralwards and downwards, and then divides, the two tubules following the posterior wall of the œsophagus. Finally, the tubules turn back upon themselves, running outward and towards the rectum. The whole excretory apparatus has thus the form of the Greek letter Υ.

Each tubule ends blindly in a flame cell which bears the characteristic cirrus, exactly similar to that found in the stalk (page 6). Figure 22 (Plate IV.) shows the end of the tubule of the left side. The plane of this section was such that it cut the posteriorly reflected region of the excretory tubule of the left side throughout all but the middle of its extent. At the middle line the tubules of both sides sink below the plane of the section, so that it is the efferent duct which is cut at *nph.* in the median plane.

One of the youngest individuals in which I have found a nephridium is that from which the section Figure 29 (Plate IV.) was drawn. The efferent duct (*neph.*) appears to be composed of two elongated cells placed end to end. Running through the midst of these is a poorly marked lumen, partly filled by a granular substance. This and one or two other similar cases seem to me to support strongly the view of the intracellular nature of the lumen of the nephridium.

The evidence derived from the adult condition is less satisfactory, but points to the same conclusion. Thus one finds on cross section of the tubules that the lumen is not sharply limited like the exterior of the tubule. In fact, one sometimes finds delicate threads traversing the lumen (Plate III. Fig. 21, *a–c*). In one of these sections two nuclei are cut across, which in so far militates against my conclusion that the lumen runs inside of single cells placed end to end. But I believe these to be the nuclei of two adjacent *overlapping* cells.

On account of the evidence just presented, I regard the nephridium of Urnatella as having an intracellular lumen and ending blindly in a

flame cell, and am thus brought into complete agreement with the results obtained by Harmer from Loxosoma. His conclusion ('85, p. 279) that the Endoproct nephridium is probably to be regarded as a head kidney, like that of Trochophores, seems to me to be justified. A further discussion of this topic must be deferred till towards the close of this paper.

The nephridium opens, as already stated, not directly into the vestibule, but into a pocket of it, the *cloaca* (Plate III. Fig. 18, Plate IV. Fig. 28). The wall of the cloaca consists of a layer of cuboidal epithelium which is perforated by three openings, — the anus, and the proximal openings of the efferent duct and of the vas deferens.

The cloaca is an organ which does not occur in any other Endoproct. Its existence here is due to the unique position of the rectum and anus, and of the opening to the vas deferens. In Loxosoma the last is very far removed from the opening of the nephridia. In the Pedicellinidæ the two openings are less distant from each other. In the male of P. Benedeni (Fœttinger, '87, Plate X. Fig. 16), the anus and the openings of the nephridium and vas deferens are quite near together; but in the female the oviduct of that species opens far distant from the other organs.

Sexual Organs. — Curiously enough, I have not found among all the individuals sectioned any ripe females. All the mature individuals of the lot collected by me on July 4th from the Schuylkill appear to have been males. In no individual did I notice any difference in the position of the ducts, such as obtains between the two sexes in Pedicellina Benedeni, — no trace of an incubatory chamber between rectum and the floor of the vestibule.

In the male organs two parts may be distinguished, — testis and vas deferens. The testis (Plate IV. Fig. 23) is a paired ovoid body lying between rectum, intestine, and the floor of the atrium. In the figure given one observes spermatozoa in various stages of development, the wall of the sac constituting the germinative epithelium.

The vas deferens (Plate III. Fig. 18, Plate IV. Fig. 28) is an unpaired U-shaped tube, the concavity of the U being turned oralwards. The wall consists of a cuboidal epithelium which is ciliated, at least at the proximal end of the tube.

The vas deferens of Urnatella resembles in form that of P. Benedeni (Foettinger, '87, Plate X. Fig. 15), which in turn seems to be more complicated than that of Ascopodaria.

Nervous System. — I have been able to make only a superficial study of this system. The main ganglion (Plate III. Fig. 18, Plate IV. Figs.

22, 29, *gn.*) lies between vas deferens and nephridium, is elongated transversely, and slightly constricted in the median plane. One can distinguish a central region composed of fine fibres running transversely, and a cortical region of cuboidal, deeply staining cells with large clear nuclei. I have not succeeded in tracing any peripheral fibres from this ganglionic mass, as Ehlers has done in another Endoproct.

III. Non-sexual Reproduction.

1. *Architecture of the Stock.*

Urnatella forms stocks by budding. As in other Bryozoa, the buds are normally produced in a very regular manner. I believe that I have determined the law in part, although it has exceptions, as the law of budding in every Bryozoan stock has. As Leidy has stated, several vertical stalks may arise from the same horizontal plate. A single stalk may remain unbranched, giving rise to new individuals at its distal end only, or it may give rise to branches which come off irregularly from a few segments. Usually only one branch arises from a single segment, but occasionally two do so (Plate V. Figs. 35, 38).

The length of these branches and the number of their segments decrease towards the distal end of the main stalk, and the conclusion seems justified that it is only at the distal end that they are formed. Excepting for these occasional branches, the lower segments of the stalk are bare of any branches or polypides. The distal end, however, is usually crowded with polypides so thickly as to make it difficult to count them or to determine their points of attachment (cf. Plate V. Fig. 30).

A very casual observation, however, shows that the buds from the main stalk are of two kinds; first, those which have given rise to a linear series of segments at the distal end of which is a calyx, and these are what I have called *branches;* and, secondly, those consisting of a *stolon*-like process, from one surface of which arise calyces resting upon a stalk of usually one segment only. The surface of the stolon upon which such polypides are placed is a definite one, namely, that which is turned towards the distal end of the main stalk. The budded branches and also the stolons are grouped upon the oral side of the adult stalk.

In the clearest cases, in young or not too richly branched stocks, I find the branch arising on the oral surface of the segment, and between two stolons, which are therefore more nearly lateral (Plate V. Figs. 37, 38, 40, 42)

One may therefore say that *usually the branches are median and oral, the stolons lateral.* Again, the branches give rise, like the primary stalk, to two kinds of buds, branches and stolons. The stolons give rise only to stalks of one segment each, bearing a calyx distally. These calyces are so placed that their oral surface is directed towards the distal end of the stolon. I have not found more than two individuals borne upon a stolon.

I have previously ('91, p. 72) tried to show how all buds in the stocks of Bryozoa are to be referred back to embryonic tissue lying at the tips or margin. In Endoprocta, however, the extreme tips seem to be occupied by a polypide, and the embryonic tissue lies in a zone at the base of the latter. This difference may be regarded, however, as only apparent, and the two conditions harmonized by conceiving the polypide in Endoprocta retracted into the stalk, below the zone of embryonic tissue, — the condition realized in Ectoprocta. The distal part of the stalk will then become terminal, constituting an apical ring of embryonic tissue surrounding the secondary atrial opening thus produced. From the oral portion of this ring new buds — branches and stolons — are, as in Plumatella, proliferated; and this process is repeated for each segment. At (or near) the apices of these incipient branches and stolons lies a mass of embryonic tissue which gives rise in the one case — branches — to the stalk, the polypide, and the *Anlage* of new buds; and in the other — incipient stolons — to the stolon and the *Anlage* of the individuals which bud forth from it. The differences between the branch and the stolon are, however, more apparent than real, as a comparison of the diagrams Figures 59 and 60 (Plate VI.) will make clear. In one case (Fig. 59) the mass of embryonic cells in any segment does not grow out far beyond the youngest individual produced from it; in the other case (Fig. 60) there is a considerable growth beyond the youngest individual. Thus in the latter case a long stolon is produced, in the former it remains at a minimum.

As I have already stated, in most cases, particularly in young vigorous stocks, one meets with the condition which may fairly be called typical, in which from one segment three buds — one median (branch) and two lateral (stolons) — arise. This typical condition may be expressed by the formula on the next page.

This formula will be understood by reference to the diagrams on Plate VI., of which it is a symbolic expression. The letters represent in all cases calyx-bearing individuals, the asterisks gemmiparous tissue. The capital A stands for the individual which forms the main stem under

consideration. The ✱ immediately below it represents the embryonic mass situated at the tip of the stalk, from which all the gemmiparous tissue distributed throughout the stock has taken its origin. As the stalk has grown, there have been left behind the embryonic masses represented by ⁎. Three of these have arisen together, and the process has been repeated as often as segments have been formed. The separation of the segments is represented in the formula by a dash. Between every two dashes the same budding process is repeated.

```
                    A
                    ✱
            ⁎       ⁎       ⁎
            ———————————————
        ⁎ × a       a       a × ⁎
                    ×
                    ⁎
            ———————————————
                ×               ×
⁎ × b       × × a       a       a × ×       b × ⁎
                ×               ×               ×
                    ×       ×       ×
                            b
                            ×
                            ⁎
```

The median embryonic masses (⁎) give rise to the individuals a, b, and c, and leave with each a dowry of embryonic tissue represented by ×. Each of these individuals a, b, and c, with its embryonic mass ×, now acts exactly like A✱. The lateral embryonic masses act precisely as do the median ones.

The typical condition expressed by the foregoing formula is not often perfectly realized, for the simple reason that the stock would thereby become too crowded. The more frequent modifications are the absence of the median bud, the absence of one or both of the lateral buds (stolons) and, occasionally, the apparent substitution of a branch for a stolon.

The foregoing formula is one of the most complicated that it is necessary to make for Bryozoa, for nowhere else are the embryonic masses so abundant relative to the polypides, or, in other words, nowhere else are so many embryonic masses borne by one individual. It is quite common among other species to find three embryonic masses arising from one, but here the formation of triple masses is repeated as often as the number of segments in the stalk. This fact raises the question of the significance of these segments, and leads us to discuss the subject.

2. *Segmentation of the Stalk.*

Leidy ('84, p. 9) did not fail to call particular attention to the division of the stalk of Urnatella into segments, and recognized their successive production "through the process of division, very much in the same manner as in the production of the proglottides of tape-worms from a *scolex*."

The phenomena of segmentation must have a special interest on account of the relation of segmentation and strobilization. I shall treat under this subject, first, of the phenomena of segmentation in Urnatella; secondly, of the probable origin and significance of the process in this genus; and, thirdly, I shall examine critically Leidy's comparison.

The transverse septum, which is the first indication of the separation of the stalk into segments, begins to be formed at about the time that the lateral buds arise, and immediately below them. It arises, as already stated (page 8), as a ring-like fold of the ectoderm, whose free edge encloses a circular orifice, through which the interiors of the two segments which are being formed are continuous (Plate IV. Fig. 24). By continued growth of this fold the diameter of the orifice diminishes, never wholly closing, but leaving a space for the passage of the tubular cells, to which reference has already been made (page 7). In this process the sheath of longitudinal muscles, which originally ran immediately inside of the ectoderm continuously from the base of the calyx to the last fully formed septum, becomes discontinuous at the place of the ingrowing fold, and the separated ends of the muscle fibres become attached to their respective faces of the septum.

In order to discover the significance of this process of segmentation we must first study its distribution throughout the Endoprocta. Usually the calyx is borne upon an unsegmented stalk. Such is the condition, for example, in Loxosoma, Pedicellina echinata, P. Americana, and Ascopodaria. In other cases, Gonopodaria (Ehlers, '90, p. 146) and P. Belgica (Fœttinger, '87, p. 301), there is a poorly expressed and highly variable segmented condition. In Arthropodaria (Pedicellina) Benedeni the stalk is distinctly and regularly segmented, there being partitions and slight external constrictions. Finally, in Urnatella we find the segmented condition still more sharply expressed.

There is a suggestive parallelism between the formation of segments and the production of buds. While with one exception all species with unsegmented stalks produce no buds, and none have yet been described

as occurring on Gonopodaria and P. Belgica, budding does occur to a slight extent on Arthropodaria, and still more profusely on Urnatella. There is one genus, however, Barentsia (Vigilius, '84[a], p. 86), which buds sparsely and has an unsegmented stalk. Here, however, as in Urnatella (Plate VI. Fig. 58) and Arthropodaria (?), there is a septum between the branches and the main stalk.

Finally, in all Pedicellinidæ which have been studied carefully there is a septum between the stalk and calyx.

One may bring these scattered facts of distribution of the septum into some sort of unity by saying that in the Pedicellinidæ every calyx and every lateral branch (where such exists) is partly cut off from communication with the interior of the mother stalk by septa. This is effected by the production of these organs at the place of junction of the calyx and the lateral buds to the stalk, and in some cases also by the partial division of the stalk itself into compartments by septa. The transverse septa must have either a morphological or a physiological significance. They might be regarded as a part of the wall of zoœcia, equivalent to the zoœcia of Paludicella, and therefore to be morphologically equivalent to the septa of Paludicella. On this hypothesis each segment of the stalk of Urnatella would be an (incomplete) individual. The idea of the individuality of the segments would seem to be sustained by the fact that each gives rise to similar buds, and that apparently any segment has the capacity of regenerating the lost calyx, or end of the primary stalk. On the other hand, dissepiments might be regarded as structures which had grown across the originally unsegmented stem to fulfil some need of the organism. Comparative anatomical studies seem to me to favor the second view. In Loxosoma, and in most marine Pedicellinidæ, we find a stalk without dissepiments. In other forms dissepiments are few and variable in number, in still others they are constant in occurrence, and from the segments arise buds. Finally, in Urnatella, the segments are separated by the dissepiments, each becomes more individualized, and has the capacity of giving rise to buds having the same arrangement. The differentiation of the separate segments has gone so far that one can hardly see in the stalk of Urnatella, resembling a string of beads, the assumed smooth cylindrical stem of its Pedicellina-like ancestors.

If we seek for an explanation of the dissepiments, I think it is to be found in the protection of the stock against the influx of water and destroying organisms at the time of the loss of calyx or lateral branches, which would make regeneration impossible. This is the same hypothe-

sis which I offered in a former paper ('91, p. 40) to account for the formation of a septum in Ectoprocta.

In favor of this hypothesis are not merely the need of such an apparatus on account of the frequent loss of the calyx and the lateral branches through accident, and the fitness of this mechanism for the function, but also the existence of the special mechanism of radiate cells, covering over the opening in the dissepiment between the calyx and stalk, — a dissepiment which will be most useful in the manner indicated by this hypothesis, owing to the delicacy of the calyx and its liability to accident. When the lateral branches or the terminal calyx become detached from the parent stem, we find that the pore in the septum, remaining behind as a part of the wall of the stalk, has become sealed by a cuticular plug. So also Ehlers ('90, p. 22) in Ascopodaria. In this case we can see the utility of the dissepiment, and can infer its value in those positions where it is not certain, but only possible, that it may be called into play. My conclusion then is, that the dissepiments have a purely physiological meaning, possessing a protective function, and that the segments of the stem are only physiological divisions of a primitively undivided stalk, which have perhaps no other significance than that they are parts separated by the dissepiments.[1]

It follows naturally from the foregoing hypothesis, that the segmentation of the stalk has succeeded, rather than preceded, the condition of bud formation from the stalk, it being rendered desirable owing to the greater danger to mutilation to which the stalk is exposed. From this standpoint we can see why buds should be produced on each segment in a similar manner. The relative profuseness of budding in Urnatella is explainable on other grounds.

Examining more closely the relation of this process to the production of proglottides in a tape-worm, — accepting the view that the production of proglottides is fundamentally a process of continual regeneration of lost parts, — there seems to be an important difference in this, that the growth of the stock of Urnatella is limited, more than ten or twelve segments being rarely formed, while an indefinite number of proglottides are produced. The limited growth of the Urnatella stem seems to indicate that the production of segments is not the production of new parts,

[1] Freely branching stocks of Hydroids have septa interpolated at the base of the hydranth, which is peculiarly liable to fall off, and sometimes in the middle of the stems. The occurrence of such similar structures throughout the two most profusely branching groups of Metazoa is further evidence for the validity of the physiological explanation of them which I have offered.

but the division, progressing towards the calyx, of an originally simple stalk into a number of parts, — that the growth of the Urnatella stalk is limited just as that of the Pedicellina stock is limited, and for the same reason.

3. *Orientation of the Individuals.*

The orientation of the individuals of the stock seems to be here, as in Ectoprocta, a very definite one. In Pedicellina and its close allies, as well as in Urnatella, the young individuals budded from the parent stalk face the same way as the polypide of the parent stock. Seeliger ('90, p. 571) has pointed out that in all the species of Loxosoma the orientation of the buds with reference to the parent is definite, but different from that found in Pedicellina. The orientation of the buds in Loxosoma (which arise, as in Pedicellina, on the oral side of the mother) is the reverse of that of the mother. Thus it comes about that the oral aspect of the buds in the Pedicellinidæ is turned towards the periphery of the stock, that of Loxosoma towards the centre. This is the same difference which has been found to prevail between the buds of Phylactolæmata and Gymnolæmata, and as in this case, so in Endoprocta the differences may be harmonized by a different method of expression. *In all Endoprocta the oral aspect of the buds is turned towards the centre of proliferation.* For in Loxosoma new individuals are produced between the next older and the parent stock, the centre of proliferation remaining in the parent stock, while in Pedicellina it migrates away upon the end of the stolon. The typical condition in Loxosoma is represented by the formula

a b c d * A;

that of Pedicellina by

* d c b a A,

in which the asterisks represent gemmiparous tissue.

The general statement of the relation of the aspects of the buds to the proliferating region is the reverse of that which I have given for Ectoprocta ('91, p. 82), which reads, "In both Phylactolæmata and Gymnolæmata, the *anal* aspect is turned towards the gemmiparous region." It is important to note, however, that this difference corresponds to a difference in respect to the part of the alimentary tract which is formed by the principal pocket of the atrium, for this in Ectoprocta gives rise to the posterior part of the elementary tract; in Endoprocta, on the contrary, to the anterior part. The differences in the process of budding in

the two groups can be harmonized, and at the same time the physiological nature of the differences indicated, by putting the statement thus: — In all Bryozoa, the formation of the alimentary tract begins at that end which is turned towards the gemmiparous region (cf. page 28).

The problem of the difference in the method of development of the alimentary tract in Ectoprocta and Endoprocta, is the same as that of the differences in the development of the alimentary tract of Triploblastica in general.

As is well known, the midgut in Triploblastica is produced by an invagination whose mouth — the blastopore — comes to be in some cases at the anterior part of the tract, in others at its posterior part. This variation in the method of formation has been explained by the hypothesis that the blastopore represents the opening into the gastro-vascular cavity of Cœlenterates, which is functionally both mouth and anus; and that as we find a physiological separation of the opening in many Cœlenterates, so a morphological separation of the gastrula-opening into mouth and anus by concrescence of the lips of the blastopore in the mid-oral line, has occurred in the ontogeny of Triploblastica. In some cases both mouth and anus arise by this process, in other cases only one organ, the other arising secondarily, or (preferably) later. The part which arises later might be regarded as a new formation, or, following Caldwell ('85, p. 23), as derived from a part of the entoderm which had become separated from the greater part in the separation of the two extremities of the elongated lip of the blastopore to permit the placing of mouth and anus at opposite poles of an elongated animal.

The application of these facts and their explanations to the facts of the formation of the alimentary tract in the Bryozoan polypide is evident. Gastrulation takes place not in the act of first invagination of the inner layer of the bud, but in a secondary invagination from the bottom of the first formed sac. The blastopore does not lie on the surface of the body wall, but has been carried below the surface, and its position is indicated by the plane of separation of alimentary tract and atrium, where the roof of the gut and the floor of the atrium have been produced[1] by concrescence of the lips of the blastopore. The atrium then is in no way lined by entoderm; it is merely a precociously developed, protecting pocket of the body wall, which occurs in that region in which invagination of the entoderm is to take place. The primary atrial opening is not at all the blastopore, as some authors have called it.

[1] Compare Seeliger, '89[a], pp. 181, 182; so also in Paludicella, see my earlier paper, '91, p. 19, and probably in Phylactolæmata, cf. Kræpelin, '92, p. 33.

My conception of the relation of the processes of atrium formation and gastrulation will be more easily understood if we compare the formation of the polypide with the early stages in the development of the egg of Sipunculus, as given by Hatschek ('83, pp. 78–81). Here gastrulation occurs only in the depths of the invagination at the vegetative pole; the more superficial part of the cavity is the trunk amniotic cavity. This corresponds to the atrium of Bryozoa, and, like it, is lined by ectoderm.

The concrescence of the lips of the blastopore takes place slightly differently in Endoprocta and Ectoprocta, so that in one case the blastopore persists in the region of the permanent mouth, and the proctodæum appears later; whereas in the other case the blastopore persists in the region of the permanent anus, and the stomadæum arises later.

In all Bryozoa, however, the main ganglion arises in the region of concrescence, precisely as the ventral nerve cord is now known to do in most invertebrates. Thus additional support is given to the idea that the ganglion of Bryozoa is a *subœsophageal* one.

4. *Histology of the Buds.*

The *histological structure* of the branches is exactly like that of the parent stalk. The minute structure of the stolons deserves a word of description. The base from which the individuals arise is filled with mesenchymatous cells, which at the distal, growing end are closely packed and deeply stainable (Plate VI. Figs. 51, 57, *sto.*). Some of the cells are differentiated into muscle fibres, which run up into the stalks of the individuals that have arisen from the stolon (Fig. 57, *mu.*). The epithelium at the distal end of the stolon is composed of cuboidal or slightly elongated cells. At the base of the stolon the epithelial cells are greatly elongated and closely packed together (Figs. 51, 57, *el. sec.*).

At the point of attachment to the parent stem the stolon is considerably constricted, the epithelium forming an inward fold surrounding a small opening through which the parenchymatous tissue of the bud and the mother stalk are continuous (Plate VI. Fig. 58, *di. sep.*). Between the layers of this circular fold is secreted a cuticular disk, perforated at its centre.

5. *Formation of New Stocks.*

The development of Urnatella from the egg has never been seen, and I was naturally anxious to get embryological material. On looking over my preserved material I found no trace of eggs, although there were many ripe males. I have no direct knowledge, therefore, as to whether

I was too early or too late for embryological material, although from some indirect evidence drawn from what follows I am inclined to think I was too early.

The youngest stocks found I obtained in large numbers, and they were of almost exactly the same age. Moreover, they agreed with the youngest stages found by Leidy and figured by him ('84, Plate I. Figs. 5, 6, 7). I have represented some of these in Plate V. Figures 31, 32, and, enlarged, in Plate II. Figure 15, and Plate V. Figure 46.

I have already (pages 3–6) called attention to some of the characters of the stalks of these young individuals. It remains to mention the "basal plate" of such stocks.

Unlike its condition in the adult, the "basal plate" is a relatively large organ of elongated cylindrical form (Plate II. Fig. 15). Its outer epithelium consists of sharply demarked cells, cuboidal above, columnar below. This epithelium has given rise to a cuticula thin and dense above, and thicker and less refractive below. The columnar cells are somewhat less deeply stained than those at the end of the "basal plate" farthest from the two stalks. Their nuclei lie at their inner ends. The outer part of the cell contains spherical masses of granules. On the whole, it stains less deeply than the inner end. Finally, one always finds particles of dirt closely adherent to the under and lateral aspects of the basal plate.

These facts I interpret as follows. The columnar cells of the under side are glandular, and secrete a sticky substance which causes the adherence of the surrounding particles of dirt, and thus serves to *anchor* the young stock.[1] The tissue of the interior of the "basal plate" is remarkable, and difficult of interpretation from sections alone. In such sections one sees bands running through the middle region and crossing at various angles. Each of these "bands" is a nucleated cell, and probably represents a muscle fibre (cf. Plate V. Fig. 46). One sees also fibres having a different appearance running radially from the base of the stalk to the columnar cells of the "basal disc" over quite a long stretch (Plate II. Fig. 15). In addition to these protoplasmic structures there are long clear spaces which are bounded by thin membranes and contain occa-

[1] Seeliger ('90, p. 573) finds in Pedicellina a glandular differentiated zone on the base of the stolon, where it comes in contact with foreign bodies. This, he says, can be traced unbroken through the entire length, especially in young stocks, consisting of few individuals. The foot gland of Loxosoma is an organ fulfilling a function similar to that of the glandular cells of the stolon, but an homology of the two organs can hardly be maintained.

sional nuclei. These are the tubular cells already referred to. Some of them contain the agglutinated cilia characteristic of flame cells, and they arise from large cells, which must indicate the beginnings of the excretory tubules of the stalk already mentioned.

What is the meaning of the fact that no younger stages than these occur, although such and all older stages are abundant? Have these young stocks been derived from fertilized eggs, or have they some other origin?

I have already referred to the fact that the great mass of the buds of any Urnatella stock are found at the upper end of the parent stalk. The lower and middle parts of the stalk possess few buds, although they once constituted the upper end of the stalk. What has become of the buds which have been lost? Leidy asked this question, and the facts led him "to suspect that the branches are spontaneously and habitually detached from the parent stem, to become elsewhere attached, and thus form new colonies." I have evidence that raises the suspicion of Leidy to as near certainty as can be obtained by use of the morphological method. *The "youngest stocks" are derived from the stolons of the parent stalk, which habitually become free for the purpose of founding new stocks.*

To establish this proposition it will be necessary to show, (1) identity of structure between old lateral buds and young stocks, and (2) the scar of attachment of the young stock to the parent stalk (cf. Plate VI. Fig. 58). Of identity of structure there can be no question. Often it would have been quite impossible to distinguish between young stocks and "stolons" which had been violently broken off from the parent stalk and were lying loose in the bottle, were it not for a single criterion, namely, the young stocks had dirt adhering to their lower surface. An application of the second criterion leads to the same positive result. In series of thin sections of young stocks one can always find at one side of the median plane the scar of former attachment, which appears as a thickening of the cuticula into which ectodermal cells may sometimes be seen penetrating (Plate V. Fig. 47). We have here, then, a method of non-sexual propagation quite similar to that obtaining in Loxosoma, where the buds habitually drop off, so that this genus is commonly said not to be stock-producing. This resemblance must be regarded as being purely a physiological one, and not in the least implying any closer relationship of the two genera.

I have already expressed my belief that the stolons are thrown off regularly *for the purpose* of founding new stocks. On this assumption we can account for the rapid growth of the embryonic tissue giving rise to a

stolon-like body, which will become a basis of support for the new stock, the "basal plate." One can thus account for the thickened cells of the under side of the stolon, which appear before detachment (Plate VI. Figs. 51, 57). The question remains, Do the median branches play a similar *rôle* to the stolons? I do not think they do, for the reasons, (1) that, having no basal plate, they are not physiologically fit for forming new stocks; (2) that I have found no new young stocks having one parent stem with one or two generations of budded individuals, — the condition of the median branches; (3) that, on the contrary, one often finds such median branches persisting on even the lower segments of the stock. (Plate V. Figs. 35, 39, 40. Compare Leidy, '84, pp. 8, 9, Plate I. Fig. 4.) Since the median branches frequently persist as a part of the parent stock, — they are not produced in the first place on every segment, — I conceive their function to be the increase of the number of proliferating points in the stock itself.

Starting with the young stock, one can find all stages of growth up to the most complicated conditions (Plate V. Figs. 33, 36, 43, 44). During the growth of the stock the basal plate gradually undergoes changes. The parenchyme becomes filled with yolk globules (Plate V. Fig. 49), and the cuticula becomes thick and dark.

Concerning the morphological significance of the basal plate a few words must be said. I regard this as a stolon morphologically equivalent to the stolon of the Pedicellinidæ. In the latter group, as is well known, the individuals are budded from the upper side of a repent cylindrical stolon, which constantly produces new buds at the growing end, and which becomes separated into segments by the formation of transverse dissepiments. There is no such stolon in the adult Urnatella, which is sharply separated from the Pedicellinidæ by this single character. The presence of a stolon in the young stock indicates a derivation from an ancestral condition possessing a stolon in the adult.

If, however, the "stolon" of the young Urnatella stock is homologous with that of the Pedicellinidæ, we ought to find it, sometimes at least, giving rise to more individuals than two, and perhaps becoming segmented. Both of these conditions are occasionally fulfilled. Leidy observed that three, four, or even five stems may arise from a common "basal plate." I have observed only three with certainty. Two cases of this are shown in Plate V. Figs. 48 and 49. In the first of the two cases distinct perforated dissepiments were observed dividing the stolon (basal plate) into three segments, out of each of which a single stalk arose.

6. *Formation of the Individual.*

Recent careful studies on the formation of the individual in other Endoprocta, especially by Seeliger ('89[a]), render a detailed study of this process less necessary. There are a few points concerning the physiological rather more than the morphological features of this process which I have attended to in this case in order to test certain conclusions which I had arrived at from the study of the earliest stages of budding in Ectoprocta.

First, the budding regions are areas of cuboidal cells, with relatively large nuclei and deeply staining plasma. Such a condition is found in both the ectoderm and mesoderm of the proliferating region (Plate VI. Figs. 50, 57). The relative enlargement of the ectodermal cells, and at the same time a bending of the whole layer outward, give rise to the first fundament of the new individual. The musculature of the new individuals is certainly not derived directly from that of the old stalk, for this takes no part in the outbending. Upon the apex of the cylindrical protuberance thus formed the polypide is produced. The details of this process I have not followed.

Secondly, the position and time of origin of the buds arising from the stalk are very definite. They make their appearance in a zone lying in the lower part of the segment (Plate VI. Figs. 50, 58–60), and shortly after the formation of the dissepiment which lies just below.

One of the questions the re-examination of which most interested me was that of the origin of the alimentary tract, since this is stated to arise differently in Endoprocta and Ectoprocta.

In an optical section of the whole bud (Plate VI. Fig. 53), it could be seen that the atrium was connected with the young alimentary tract at the oral end only. The same thing is shown in the series of transverse sections, Figures 54–56, in which the distal (anal) part of the atrial chamber is not confluent with the rudiment of the alimentary tract which touches its floor, Figure 54, but the two organs are confluent at the proximal (oral) part, Figure 56. Figure 52 is from an optical longitudinal section of the bud shown in Figure 53, taken in a plane perpendicular to that of Figure 53. Here the alimentary tract, *at.* (Fig. 52; *gn.* Fig. 53) is being constricted off from the atrium.

Like the young bud, the growing tip of the stolon possesses an ectoderm consisting of large cuboidal cells (Plate VI. Fig. 57). The mesenchymatous tissue also consists of thickly crowded, undifferentiated, and deeply staining cells (Figures 51, 57).

7. *Regeneration.*

Like other Endoprocta, Urnatella has the capacity of regenerating its lost calyces. Leidy ('84, p. 13) had already observed this process, and Potts and I have (as previously mentioned) seen the same thing. Figures 3 and 2 (Plate I.) show some of the phenomena of regeneration. The formation of a new terminal calyx seems to be preceded by the formation of the stalk part of the new terminal individual. This new formation takes place in one of the segments near the distal end of the parent stalk. The terminal dissepiment of the segment, cutting it off from the outside world, is completely closed in its centre by a cuticular plug. This cuticular dissepiment (Fig. 2, *di. sep.* at the left) becomes torn off from the lateral cuticula of the segment along one edge, sometimes, as in the figure, remaining attached at the opposite edge. I have given on Plate I. (Fig. 3) a drawing of such a regenerating stalk before the polypide has budded from its wall. The outer body wall has evidently taken the initiative in the process, and mesenchymatous cells have migrated in. The drawing (Fig. 3) was made from the living animal, and the mesenchymatous cells could be seen changing form like an amœba. The amœboid cells also contained highly refractive granules, which I regard as food material. These granules were seen moving about in the cells as the latter changed in form.

One striking feature of the young segment was the presence of two flickering organs, which I now fully believe to be flame cells with their tufts of fused cilia. I have elsewhere ('91, p. 39) called attention to the part played by amœboid cells in Paludicella on the nutrition of the young buds. I believe that the amœboid cells here have the same function.

Leidy ('84, p. 13) has suggested that the segments of Urnatella might function as statoblasts to preserve the species during the winter. Of the correctness of this suggestion I have no doubt. The ease with which regeneration occurs from the old segments, and the fact that in stalks in which the calyces have been for a long time lost one sees the cirri of the flame cells still flickering, show that the tissue surrounded by the thick cuticula of the segments has a great capacity for retaining life, and, under favorable conditions, for reproducing lost parts. In their *rôle* as statoblasts, the segments need the yolk stored up in their cells during the summer.

IV. Affinities of Urnatella.

From the frequent opportunity that I have had successfully to compare the organs of Urnatella, even in detail, with those of Pedicellina and allied genera, there remains no doubt in my mind of its close relationship to those forms. Arthropodaria, especially in its segmentation of the stem and the associated budding process, seems most closely to resemble Urnatella. In three points of importance, however, Urnatella differs from other Pedicellinidæ, namely : (1) in the possession of a cloaca (and absence of a brood-sac ?) ; (2) in the presence of water or excretory canals in the stem and calyx, — which are so striking that they could hardly have been overlooked if they occurred in other Pedicellinidæ; and (3) in the absence of the stoloniferous type of budding.

As for the last difference, however, I have tried to show that there is a stolon from which the individuals of the Urnatella stock arise, although it is small. Whether this rudimentary condition of the stolon is an ancestral or a degenerate character is doubtful ; I have been inclined to consider it the latter.

In regard to the first difference, I must point out that in the male of Arthropodaria there is a condition resembling that found in Urnatella, for in the former genus (Foettinger, '87, Plate X. Fig. 8) the anus, vas deferens, and excretory tubule open near together.

The second difference concerns a very important set of organs, and if they should be shown to be indeed absent in Arthropodaria Benedeni, it would lead us to conclude that in one respect at least, perhaps owing to physiological needs, Urnatella has retained a more ancestral condition than its near allies.

V. Affinities of the Bryozoa.

There are three prevailing views concerning the relationship of the Bryozoa to other groups. According to one view (most recently and ably defended by Ehlers) they find their nearest allies in the Gephyrea ; according to the second view, they have sprung from the lower worms, — from Rotifer-like ancestors. The third view (that of Hatschek) assumes that Ectoprocta and Endoprocta are in fact not closely related, but that the former should be placed near the Gephyrea, the latter close to the Rotifera.

The reasons for this difference of opinion are not far to seek. Those who have begun their studies with the Ectoprocta, particularly with

their anatomy, have been struck by their resemblance — especially in the possession of a body cavity and of a tentacular corona — to the Gephyrea, and particularly to Phoronis. Those, on the contrary, who have devoted their studies chiefly to the Endoprocta, and especially to the development of that group, have urged the second view. The third view seeks to reconcile the two conflicting theories. I favor the second of the views given above because of certain considerations which follow.

I propose first to show the untenableness of the third view. It would then be nearly sufficient, in deciding between the two remaining views, to show that the Endoprocta are the more primitive group of Bryozoa; but in addition to this, I shall offer positive evidence of derivation of the Bryozoa from the lower worms.

The chief argument for the diphyletic origin of Bryozoa rests on these three important differences between Ectoprocta and Endoprocta: (1) that of the tentacular corona, which includes within it the anus in one case, and leaves it outside in the other; (2) that of the body cavity, which is absent in one case and present in the other; and (3) that of the kidney, which is a pronephridium in Endoprocta and (it is alleged) a metanephridium in Ectoprocta.

I have, in an earlier paper ('91[a], p. 103), shown that the difference in relations of the anus to tentacular corona is completely and satisfactorily explained by the study of the development of the polypide, in which the closure of the tentacular corona between mouth and anus is effected only at a relatively late stage.

Concerning the second of these differences, Ehlers ('90, pp. 152, 154) has already well argued that it cannot be so fundamental, since other unquestionably closely allied groups (e. g. Hirudinea and Chætopoda) differ similarly. Moreover, the difference between the "body cavity" of Gymnolæmata and Endoprocta is one of degree, not of kind, for in both cases we have to do with parenchymatous tissue more or less completely filling the primary body cavity. The existence of spaces in the midst of the parenchyme of Gymnolæmata may be accounted for (following Harmer, '85, p. 64, see also Lang, '88, p. 77) on the physiological ground of the necessity of a space into which the polypides can retract. In Phylactolæmata this parenchyme has become, in part, a very definite "cœlomic epithelium," although, as I have pointed out ('90, p. 128), showing traces of its parenchymatous origin.

Upon the alleged differences in the kidney, no argument can be based, simply because the existence of an excretory tubule in Ectoprocta is very uncertain, being at present not even probable.

A fourth difference, which I do not remember to have seen mentioned, concerns the position of the sexual glands. In Endoprocta they arise on the polypide and are connected with the atrium by a special duct. In Ectoprocta they arise on some part of the body wall. In all cases, however, they arise from the mesenchymatous tissue, or its equivalent, the cœlomic epithelium. The exact position is not significant, for even within the group of Phylactolæmata we find the testis arising sometimes on the funiculus (Plumatella), sometimes on the body wall (Cristatella), and in neither case at the same place with the ova.

On the other hand, the resemblances between Ectoprocta and Endoprocta are striking: in both a curved alimentary tract, with tentacles of similar histological structure; in both, an atrium originating in the same manner; the central nervous system in both alike in position, form, structure, and development; in both the polypide originating in comparable ways, involving the same problem of the relation of the germ layers to the organs of the bud. Moreover, there must remain unmentioned many minor resemblances which individually are not very significant, but which, occurring together, furnish a most powerful argument to the mind of one studying the animals themselves.

Hatschek's view seems to me, therefore, untenable, and it remains to inquire whether the Bryozoa have been derived, accompanied by degeneration, from an Annelidan ancestry, through Gephyrean-like forms,[1] or whether they represent a persisting low type. As we have seen, the first hypothesis must be relinquished, if it can be shown that the Endoprocta are the more ancestral type.

In any group of sessile, colonial animals, we should expect the more ancestral type to retain more distinctly its individuality, to possess in a more marked degree features belonging to a free, non-colonial life, and in a less marked degree those belonging to a sessile, colonial one. Thus in its development the group will lose certain characters and gain certain others.[2] A well marked individuality accompanied by a simple

[1] As is well known, Hatschek ('83, p 69) has long maintained that Phoronis and the Sipunculaceæ have not been derived from Annelids as the Echiurida have, but from unsegmented ancestors; and this view has become very widely accepted. Ehlers, however, seems to adhere to the older view. Whatever the truth may be in regard to this matter, the validity of my argument based on embryology and comparative anatomy concerning the absence of close relationship between Phoronis and Bryozoa is not affected

[2] Lang ('88) has shown, by an instructive analysis, that in sessile animals locomotor and sense organs, the nervous system, and the musculature tend to degenerate, and that the tentacles and protective coverings become more important.

method of budding (Loxosoma); a relatively poorly developed, incompletely retractile lophophore; a complicated system of sense organs and nerves (Loxosoma); sexual and excretory ducts; a typical larval (trochophore) form, — these distinguish the Endoprocta. On the other hand, the Ectoprocta are marked by a loss of individuality (existence of cœnocœl, Phylactolæmata), by a highly complicated lophophore provided with means for complete retraction, by absence of a complicated nervous system (small ganglion of Gymnolæmata), by absence (?) of sexual and excretory ducts, and by abbreviated larval life (passed within the body of the mother).

Stronger than this argument is the fact that in the development of the tentacular corona and of the alimentary tract — at first without a cœcum — Ectoprocta pass through stages more nearly resembling the adult Endoprocta condition than their own adult condition does.

These facts seem to me to prove, if morphological principles can be relied upon, that Endoprocta are nearer the ancestral form of Bryozoa than Ectoprocta.

Admitting that the Endoprocta are more ancestral than the Ectoprocta, I cannot conceive how any one can maintain a close relationship with Phoronis. For the line connecting mouth and anus is in Endoprocta ventral, while the corresponding line in Phoronis is dorsal, as Caldwell ('83, p. 372) has shown, and the kidney is a metanephridium. These facts far outweigh, in my opinion, similarities in tentacular corona, epistome, and bent alimentary tract.

The absence of a true body cavity, and the existence of a water or excretory system ending in flame cells, point conclusively to an origin of Bryozoa from the lowest worms. For such an excretory system is found elsewhere only in Platyhelminthes, Rotifera, and in a modified form in Nemertines (Bürger, '91). On the other hand, the existence in the stalk of epithelial (in addition to mesenchymatous) muscles looks like an advance beyond Rotifera and Platyhelminthes. But it does not follow that such muscles existed in the ancestors of Endoprocta; they may have been produced by causes similar to those by virtue of which they occur in Nematodes.

Hatschek ('77, p. 528) suggested, and Harmer ('85, p. 11, 35) has since shown, that the ganglion of the Endoprocta is to be regarded as a subœsophageal ganglion. Zelinka's ('91, p. 337) discovery of a subœsophageal ganglion in Rotifers is interesting in this connection, as making more probable the assumption necessary for the preceding view, that the ancestor of Rotifers and Endoprocta possessed such an organ.

One cannot refrain from noticing the similarity in the relations of the "under lip" of Rotifers (Zelinka, '91, Taf. III. Fig. 55) and the epistome of Bryozoa (cf. also the foot of Mollusks).

Zelinka has also shown (p. 397) that in Callidina at an early stage two lateral folds appear on the ventral side of the embryo, enclosing between them the mouth and under lip. These folds extend along about one half of the length of the embryo. Later they become relatively shorter, and finally form the lobes of the wheel organ. They have also precisely the position of the lophophoric ridges of Ectoprocta at an early stage, as I have figured it ('91, Fig. 25), lying on each side of the mouth and ganglion. They have also the same relations as the ridges from which the gill filaments arise in Lamellibranchs. Lankester's ('74, p. 80) view of the homology of the tentacles of Bryozoa and gill filaments of Lamellibranchs is thus strengthened.

Finally, there is between Rotifers and Endoprocta a striking similarity in the position of anus and urogenital ducts, which in Urnatella, as in Rotifers, open into a common cloaca on the subœsophageal aspect between mouth and anus. Such a resemblance is especially striking in footless genera like Asplanchna (which, however, has no anus, cf. Masius, '91, fig. 1) and Hertwigia (L. Plate, '85, Fig. 7), — genera resembling more nearly the ancestral form, since the foot, lying behind the anus, must be considered as a secondarily produced appendage.

To sum up: The embryological as well as the anatomical evidence seems to sustain the view that Bryozoa are closely related to Rotifers, the two groups having sprung from an ancestor which was common to them and Mollusks also; that after the Rotifer stem had branched off, the common Mollusco-Bryozoan stem produced tentacles on the lateral ridges; that the two groups then soon separated, the Mollusca to undergo an extensive and complicated development, the Bryozoa to remain at a low level. The chief changes which the Bryozoa have experienced are (1) the acquiring of a body-cavity through the relative decrease in amount of the mesenchyme, that which remains forming an epithelium (Phylactolæmata); (2) the loss (?) of the protonephridia and sexual ducts in Ectoprocta; (3) the loss of the epistome (Gymnolæmata); (4) the loss of the preoral ganglion; (5) the acquiring of a cœcum (Ectoprocta); (6) the multiplication of methods of reproduction, by regeneration, by budding (without and with stock-formation), by division of stocks, and by statoblasts.

CAMBRIDGE, September 27, 1892.

Summary.

The segmented stem of Urnatella consists of a two-layered cuticula; an outer epithelium (ectoderm) consisting of cells flattened except at the transverse septa and at the distal end of the stalk; and an axial portion consisting of elongated cells, many of which are vacuolated, and surrounding which there is no intercellular substance. (Pages 4, 5.)

The musculature of the stalk consists of radial sheets of fibrillæ, several of which develop in a single cell. (Pages 5, 6.)

Many of the vacuolated cells of the stalk end in flame cells like the water or excretory tubules of Platyhelminthes. (Pages 6, 7.)

Yolk is developed in the cells at the base of the stalk, first as fine intercellular granules, which later fuse, this process being accompanied by cell degeneration. (Pages 7, 8.)

The lip of the atrium contains a sphincter, and resembles in its relations the "margined thickening" of Ectoprocta. (Pages 9, 10.)

The epithelium of the tentacles encloses a parenchymatous core. A pair of muscles is present. (Page 15.)

The alimentary tract resembles that of the Pedicellinidæ, except that the lower wall of the rectum and the upper wall of the intestine are in close contact. (Pages 11, 12.)

The nephridial tubules end blindly in flame cells, and open into a cloaca, into which open also anus and the vas deferens. (Pages 14,15.)

Two kinds of buds arise from the Urnatella stalk; "branches," which are typically median, and "stolons," typically lateral. (Page 16.)

The segmentation of the stalk is probably an adaptation to the process of budding, which is accompanied by a greater liability of the wall of the stock to rupture, and therefore by a greater need of separation of the stalk into compartments. (Page 20.)

In all Endoprocta the oral aspect of the buds is turned towards the centre of proliferation, and in all Bryozoa the aspect in which that end of the alimentary tract which arises from the principal outpocketing of the atrium lies is turned towards the gemmiparous zone. (Pages 22, 23.)

The youngest stocks found consisted of a stolon bearing two individuals. This has been derived from the "stolons" of the parent stalk, which habitually become free for the purpose of founding new stocks. (Page 26.)

Urnatella is, structurally, one of the Pedicellinidæ and most nearly resembles Arthropodaria Benedeni. (Page 30.)

The Bryozoa have probably been derived from Rotifer-like ancestors. (Page 34.)

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ANALYTICAL INDEX

TO DAVENPORT '90, '91[a], AND THE PRESENT PAPER.[1]

The Roman numerals refer to these three papers in the order of publication. The Arabic numerals refer to pages. Topics are arranged alphabetically, except under "Groups," where the main divisions are arranged according to an adopted zoölogical system. Under "Organography" letters are placed after certain page numbers to designate the standpoint from which the organ is treated. The letters apply to all the page numbers between them and the next preceding letter. These letters have the following significations: A, Anatomy; F, Function; H, Histology; O, Ontogeny; P, Phylogeny.

Authors.

[1] See "Literature Cited," p. 36.

BIOLOGY.

BUDDING, GENERAL.

BUDDING, SPECIAL.

DEGENERATION, ii. 64.

HISTOLOGY.

PHYSIOLOGY.

REGENERATION.

RELATIONSHIPS.

EXPLANATION OF PLATES.

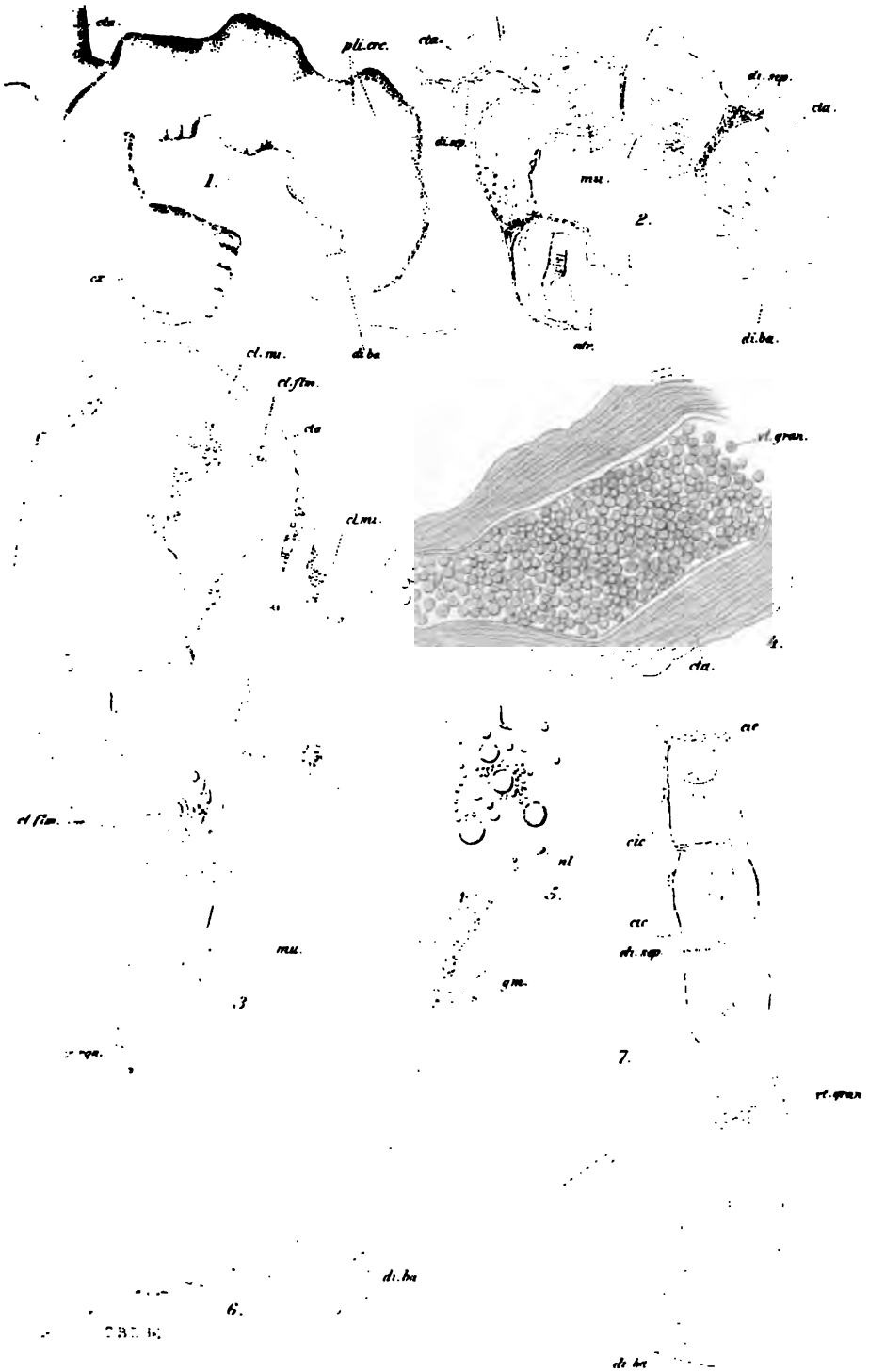
All figures were drawn with the aid of a camera lucida, from preparations of Urnatella gracilis, unless otherwise stated.

PLATE I.

ABBREVIATIONS.

atr.	Atrium.	*di. ba.*	Basal disk.
cic.	Scar of fallen-off bud.	*di. sep.*	Transverse septum.
cl. flm.	Flame cell.	*gm.*	Bud.
cl. mi.	Migratory cell.	*mu.*	Muscle fibre.
cta.	Cuticula.	*nl.*	Nucleus.
cx.	Calyx.	*pli. crc.*	Circular folds.
cx. rgn.	Regenerating calyx.	*vt. gran.*	Yolk granules.

Fig. 1. Regenerating stalk of Urnatella, viewed as an opaque object. × 96.
" 2. Optical section of the same. × 96.
" 3. Optical section of the distal end of a stalk of Urnatella which is probably about to regenerate, from living animal. × 410.
" 4. Optical section of the proximal urn of the stalk of Urnatella. Showing thick cuticula and yolk granules. × 165.
" 5. Contents of proximal urn, obtained by crushing. Moving cilia were visible. Nuclei in some of the yolk granules. × 320.
" 6. Stock of Urnatella viewed as opaque object. Three stems arising from the basal disk. Buds and regenerating terminal calyces. × 36.
" 7. Optical section of stalk of Urnatella. × 96.


cla.
pli.orc.
cla.
di.sep.
cla.
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mu.
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di.ba.
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nl
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cic
cic
di.sep.
gm.
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cl.gran
di.ba
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di.ba

PLATE II.

ABBREVIATIONS.

atr.	Atrium.	*gn.*	Ganglion.
cl. flm.	Flame cell.	*in.*	Intestine.
cl. hp.	Hepatic cells.	*ms'drm.*	Mesoderm.
cl. sec.	Secreting cells.	*mu.*	Muscle fibre.
cl. tb.	Tubular cells.	*nl.*	Nucleus.
cta.	Cuticula.	*nph.*	Nephridium.
cta.'	Outer cuticula.	*œ.*	Œsophagus
cta.''	Inner "	*of. atr.*	Atrial opening.
di. ba.	Basal disk.	*pa'chy.*	Parenchyme.
di. sep.	Dissepiment.	*rt.*	Rectum.
ec'drm.	Ectoderm.	*rt.* or *vt. gran.*	Yolk granules.
ga.	Stomach.		

Fig. 8. Longitudinal section through proximal part of stalk of Urnatella. Third stage in the formation of yolk granules. × 610.

" 9. Cross section through distal segment of stalk, showing ectoderm and parenchymatous tissue inside. × 405.

" 10. Third stage in the development of the stalk muscles. Zeiss, $\frac{1}{12}$ oil immers., Oc. 2. × 1350.

" 11. Second stage in the development of the stalk muscles. × 1350.

" 12 Termination of excretory tubule of stalk in flame cell. The position of the calyx is above. × 305.

" 13. First stage in development of yolk in stalk. × 610.

" 14. Second stage in development of yolk in stalk. × 610.

" 15 Median section through young stalk (age of Fig. 31 in Plate V). × 165

" 16 Fourth stage in the development of the stalk musculature. × 1350

" 17 First stage in the development of the stalk musculature. × 1350.

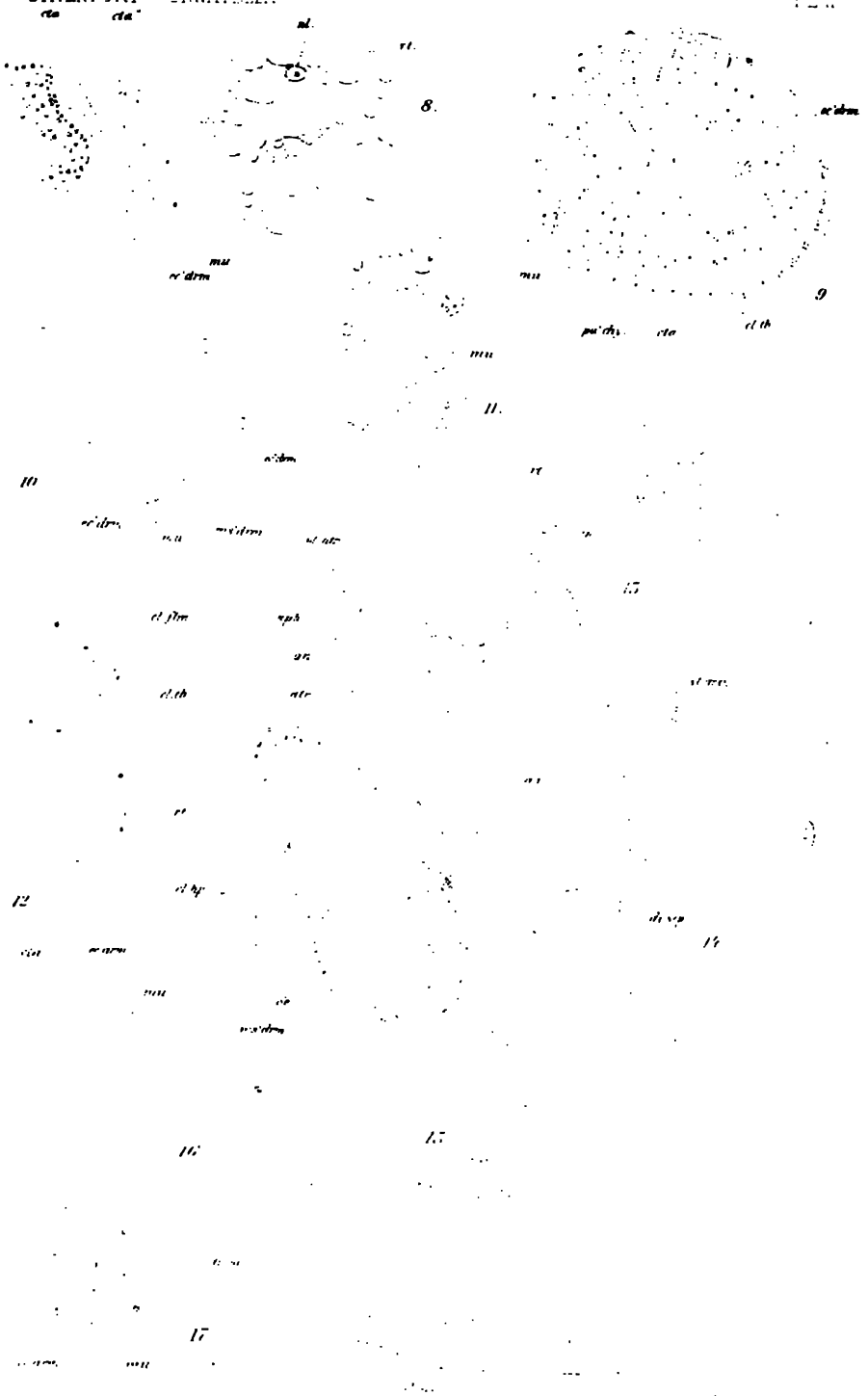
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PLATE III.

ABBREVIATIONS.

an.	Anus.	*mu.*	Muscle fibre.
atr.	Atrium.	*nph.*	Nephridium.
clc.	Cloaca.	*œ.*	Œsophagus.
cl. cls.	Closing cell of septum.	*pd.*	Stalk.
cl. hp.	Hepatic cells.	*rt.*	Rectum.
cta.	Cuticula.	*sph.*	Sphincter between intestine and rectum.
di. sep.	Dissepiment.		
gu.	Stomach	*sph. atr.*	Atrial sphincter.
gn.	Ganglion.	*sul. atr.*	Atrial groove.
in.	Intestine.	*ta.*	Tentacle.
kmp'dm.	Kamptoderm.	*va. def.*	Vas deferens.
loph. atr.	Atrial ridge.		

Fig. 18. Median section of calyx of Urnatella. Camera drawing made from several adjacent sections. × 405.

" 19. Section through plane of line "Fig. 19" on Fig. 18. × 96.

Figs 20, 20ᵃ Longitudinal and cross sections through chief nephridium of calyx × 610

" 21ᵃ, 21ᵇ, 21ᶜ. Three sections taken across nephridium of one individual at different places, to show nature of the lumen and wall Fig 21ᵃ nearer the distal end of tubule Fig 21ᶜ, third section from mouth of tubule, at point of union of two nephridia into one. × 700.

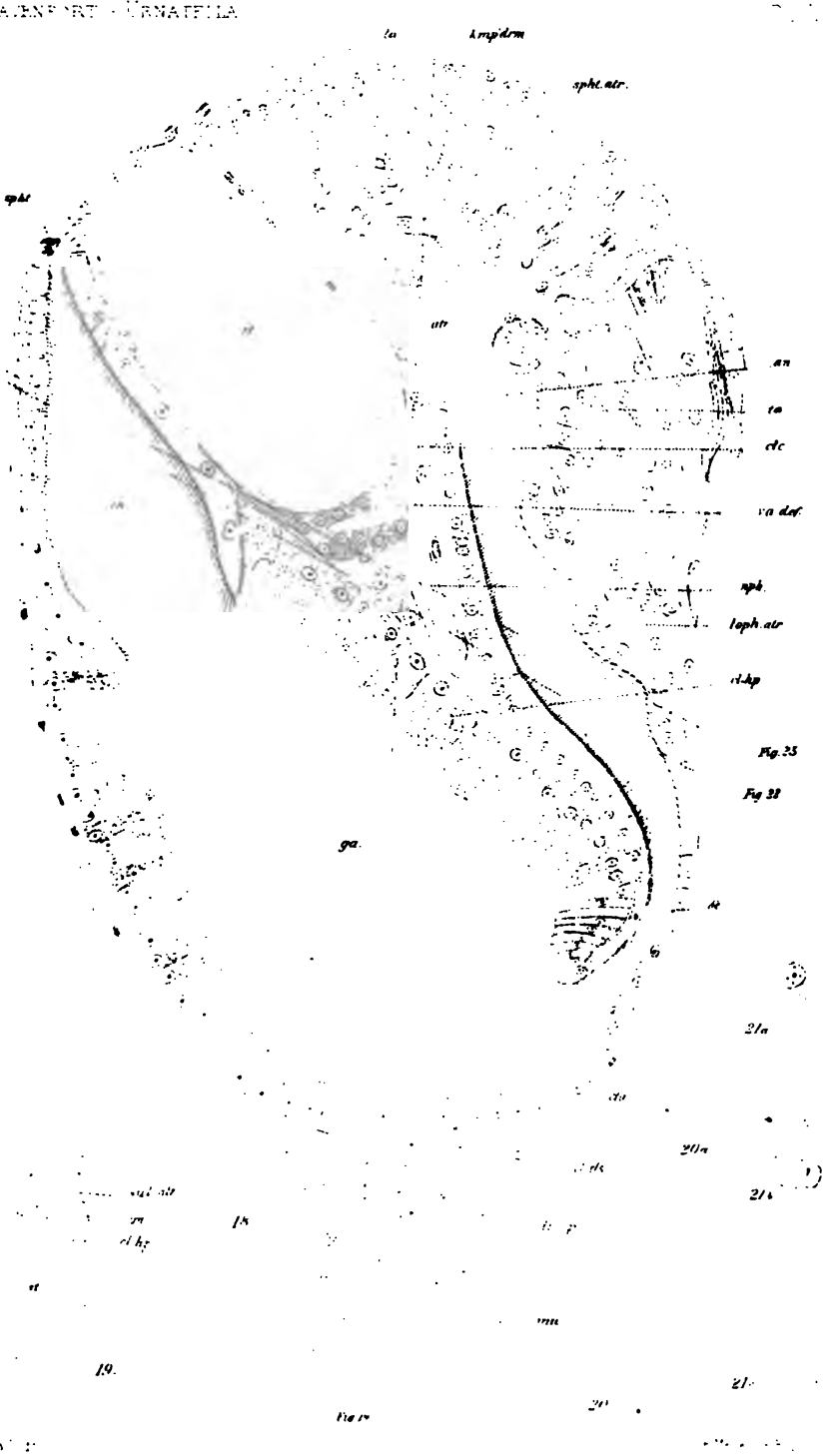
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Fig. 25
Fig. 28
ga.
21a
20a
21b
18
19.
21c
Fig. 1

PLATE IV.

ABBREVIATIONS.

an.	Anus.	*mu.*	Muscle fibre.
atr.	Atrium.	*mu. ret. ta.*	Retractor muscle of tentacle.
clc.	Cloaca.	*neph.* or *nph.*	Nephridium.
cl. cls.	Closing cell.		
cl. flm.	Flame cell.	*œ.*	Œsophagus.
cl. tb.	Tubular cell.	*pa'chy.*	Parenchyme.
cta.	Cuticula.	*rt.*	Rectum.
di. sep.	Dissepiment.	*spht. atr.*	Atrial sphincter.
ec'drm.	Ectoderm.	*sp'z.*	Spermatozoa.
gn.	Ganglion.	*te.*	Testis.
int.	Intestine.	*va. def.*	Vas deferens.

Fig. 22. Section through calyx at level indicated by line "Fig. 22" in Fig. 18 × 405.

" 23. Section through calyx above the last at level indicated by line "Fig 23" in Fig. 18. × 405.

" 24. Longitudinal section through young stalk showing development of septum. × 405.

" 25. Transverse section through closing cells at base of calyx. Section passes through a flame cell at the left. The lower part of the section lies below the dissepiment, the position of which is indicated by the line *di. sep.* × 670.

" 26. Longitudinal section through tentacle and atrial sphincter. × 405.

" 27. Two adjacent tentacles cut transversely near their bases. × 405.

" 28. Part of nearly median section of calyx, passing through cloaca and vas deferens. × 405.

" 29. Median section through nephridium aud adjacent organs of young calyx to show the development of the nephridium. × 1000.

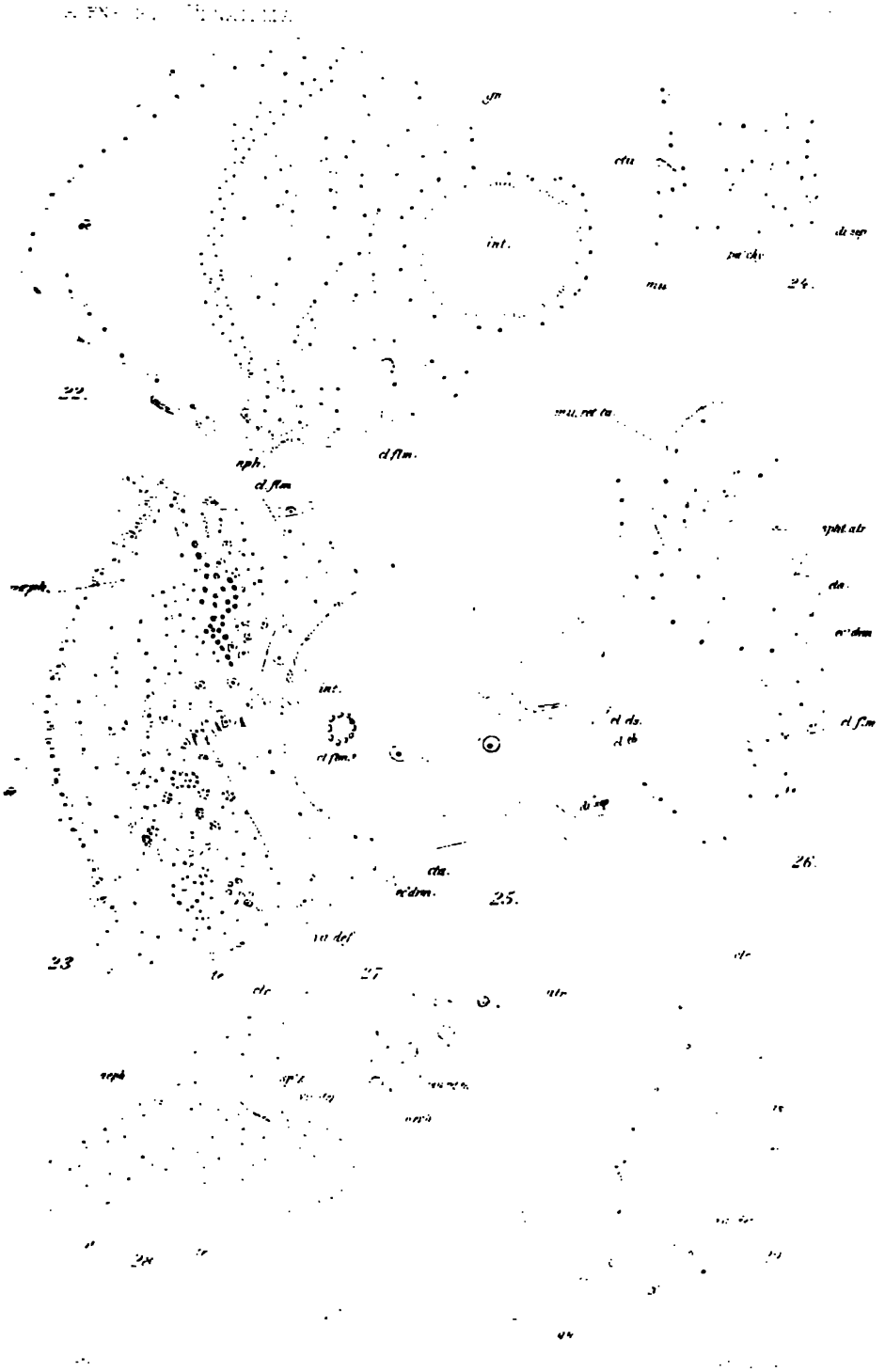
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PLATE V.

ABBREVIATIONS.

An.	Anal aspect.	*Or.*	Oral aspect.
cic.	Scar of fallen bud.	*or.*	Mouth.
cl. sec.	Secreting cell.	*pd.*	Stalk.
di. ba.	Basal disk.	*rt.*	Rectum.
ec'drm.	Ectoderm.	*sto.*	Stolon.
mu.	Muscle fibre.	*vt.*	Yolk spherules.

Fig. 30. Distal end of a richly branching stock of Urnatella, seen from the right side. × 56.

Figs. 31–45. Views of Urnatella as solid object (exc. Fig. 33). All × 18½.

" 31, 32. "Youngest stage" of Urnatella stock. Cf. Plate II. Fig. 15.

Fig. 33. View of somewhat older stage, as transparent object. Disk adhering to stolon.

Figs. 34, 35. Young stalks with median buds.

Fig. 36. Entire stock of Urnatella, — three stalks arising from one basal disk "Median buds" arising.

" 37. Stalk with two lateral buds and one median.

" 38. Stalk with profuse lateral budding on the median buds. Anal view, branches displaced to the right and left. From segment *c'* two lateral buds and one median have arisen; from *c*, two lateral buds, one of which has given rise to two individuals, the other to only one

" 39 Stalk with branches, — oral view. Remnant of a median branch on segment F. From *c'* two lateral (¹) buds; from K a stolon with two individuals, and from L two stolons, the left with two individuals, the right with one.

Figs. 40, 41. Branching stocks with median and lateral buds.

Fig 42 Typical lateral buds, each with two individuals. A median bud on next younger segment

Figs 43, 44 Right and left views of the same stock. The number of individuals is indicated in the diagram accompanying the figures (Fig. 44[a])

Fig 45. Left view of part of stock. Two stolons and one median branch from segment B (Fig. 45[a]).

" 46 Optical section of "youngest stage" of Urnatella stock Stolon with two individuals arising therefrom × 120.

" 47 View of cuticula and ectoderm at end of a stolon in a stock of the "youngest stage," showing scar of former attachment to parent stock × 405

" 48 Optical section of the basal plate of a stock showing three individuals arising from it, and its division into three segments × 52

" 49 Three individuals arising from an older basal plate. × 52


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pd
dbu
d.sc

PLATE VI.

ABBREVIATIONS.

atr.	Atrium.	*i.*	Inner layer of bud.
cl. sec.	Secreting cell.	*mu.*	Muscle fibre.
cx.	Calyx.	*or.*	Mouth.
di. sep. or *di. sp.*	Dissepiment.	*sphi. atr.*	Atrial sphincter.
		st.	Stomach.
ex.	Outer layer of bud.	*sto.*	Stolon.
ga.	Stomach	*ta.*	Tentacle.
gm.	Bud.		

Fig. 50. Surface view of stem stained in Czokor's cochineal and studied in clove oil. Showing the deeply stained protoplasm and crowded condition of nuclei indicating the position of an incipient bud. × 318.

" 51. Lateral bud drawn as transparent object after staining, showing stolon and secreting cells (*cl. sec.*). × 98.

Figs. 52, 53. Two optical sections from different aspects of the same bud stained in Czokor's cochineal and studied in clove oil. Showing formation of alimentary tract. × 225.

" 54–56. Three transverse sections across a young bud, showing the development of the alimentary tract. Fig. 54 nearest the tip; Fig 56 nearest the base. × 405.

Fig. 57 Enlarged view of lateral bud showing stolon and secreting cells (*cl. sec.*). × 205.

" 58. Stalk of young lateral (?) bud showing method of attachment to adult stalk. × 285.

Figs. 59, 60. Two diagrams showing relation between the two methods of budding in Urnatella. The shaded cells indicate probable position of embryonic tissue.


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52.
53.
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56.
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58.
59.
60.

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XXIV. NO. 2.

NOTE ON THE CAROTIDS AND THE DUCTUS BOTALLI OF THE ALLIGATOR.

BY C. B. DAVENPORT.

WITH ONE PLATE.

CAMBRIDGE, U. S. A.:
PRINTED FOR THE MUSEUM.
JANUARY, 1893.

No. 2. — *Note on the Carotids and the Ductus Botalli of the Alligator.* By C. B. DAVENPORT.[1]

THE carotids of the Alligator, as is well known, usually present in the adult an unsymmetrical condition. From the right aortic root two branches (*a* and *b*) arise close together. Of these, one goes to the left, the other to the right side of the body. The left vessel (*a*) gives rise first to a large artery (1) running on the dorsal side of the œsophagus to the head; secondly, to a smaller one (2) running alongside the neck, sending branches to the œsophagus, trachea, and muscles of the body wall, and anastomosing behind the occiput with a branch of 1; and, thirdly, to a vessel (3) going to the fore limbs. Other smaller vessels we may for present purposes neglect. The right vessel (*b*) gives rise to all that the left does excepting the equivalent of 1.

Concerning the homology of these vessels with those of other Reptiles and of Birds, there has been much difference of opinion. Rathke ('57, p. 91) designated the vessels *a* and *b* arteria anonyma. He called 1 art. subvertebralis, and from embryological data he interpreted it (as defined in the preceding paragraph) as follows. The right and left common carotids arise separately, and later fuse along the middle of their extent, but remain separate at their proximal and distal ends. Secondarily, the right proximal root degenerates, and is thus absent in the adult.

By "common carotid," Rathke implies an homology with a vessel of this name in Lizards. The latter is morphologically equivalent to the *ventral distributing trunk* between the third and fourth arterial arches in Rathke's well known type scheme of the arterial arches. The unfused distal ends of the common carotids each branch at the occiput to form vessels homologous, in his opinion, to the internal and external carotids of Mammals.

Fritsch ('69, p. 705) later maintained that the a. subvertebralis is an a. carotis primaria, i. e. produced by a drawing out of the a. anonyma,

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXIV.

and hence essentially unpaired, — a view which Hoffmann in Bronn's Thierreich, Reptilia, unfortunately adopts.

Van Bemmelen ('88, pp. 114, 115) combats the view of Fritsch, and brings forward additional instances of the persistence of the right proximal root of the a. subvertebralis in embryos. At the same time he points out that Rathke's a. subvertebralis must be regarded as equivalent to the dorsal collecting trunks of the anterior branchial vessels, and therefore to the aa. carotides internæ of Rathke's general scheme. The vessels designated in my description above by the numeral 2 — called by Rathke a. collateralis colli — are, on this hypothesis, to be regarded as aa. carotides externæ (ventral distributing trunks of anterior branchial vessels).

Mackay ('89, pp. 126–136) more than any other has contributed by his embryological and comparative anatomical studies to an interpretation of the carotids of the Crocodilia. The vessels *a* and *b* are, according to him, the parts of the ventral distributing trunks which lie between the fourth and third arches, and correspond to the common carotids of Rathke's general scheme. The morphologically paired vessels (1) are the combined internal, or, better, "dorsal" carotids. The part designated in Figure 1 by 1^a is thus homologous with the third visceral (first branchial) vessel. The part designated by $1^b + 1^{b'}$ has arisen by fusion of the dorsal collecting trunks of the three anterior branchial vessels through a part of their extent. The vessels marked 2 and 2′ (Fig. 1) are external or "ventral" carotids, — these vessels being represented in Birds also, where the so called common carotids are in reality "dorsal" carotids, not equivalent to the common carotids of Lizards. Mackay's results, which thus confirm and extend van Bemmelen's, seem conclusive, not only because he has traced the development of the homologous vessels in Birds, but because he has found one instance — like that of Brandt ('72, p. 307) long ago — in which the dorsal collecting trunk persists between the third and fourth arches. It is connected with the third arch near the proximal (posterior) end of the a. subvertebralis, and is thus far removed from Rathke's so called "a. carotis interna" of the head region. The hypothesis that the a. collateralis colli of Crocodiles is homologous with the a. carotis externa of Lizards, receives additional support from the fact that, as in Birds, the a. subclavia arises near the point at which the a. collateralis colli is formed by the division of the true a. carotis communis (*a* and *b*).

The conclusions of Mackay have been recently confirmed by the researches of Hochstetter ('90).

In view of the interest attaching to this subject, I have thought it not wholly superfluous to put on record still another example of the persistence of the right root of the a. subvertebralis, — especially since so perfect a root from so old a specimen has not been heretofore mentioned, and since no figure of this condition at any stage has, to my knowledge, been heretofore published.

The specimen in question was one which was being used for study in the class in Vertebrate Anatomy by one of my pupils, Mr. H. O. Marcy. The Alligator was about 28 cm. long. The arteries had been injected from the heart, and a very evident branch, Figure 1, $1^{a'}$, was shown, fully injected, running from the right common carotid, *b*, to the a. subvertebralis $1^{a} + 1^{b'}$. Thus the whole carotid system had a very symmetrical aspect. The branch in question ($1^{a'}$), which must be regarded as the proximal end of the right dorsal carotid, was injected throughout its whole length. It measured 0.7 mm. in diameter, the corresponding measurement of the left root being 1.0 mm. The two trunks passed dorsally, encircling the trachea and œsophagus, and met near the median plane, dorsal to the œsophagus and immediately beneath the vertebral column.

I add also figures of two cases of persistent ductus Botalli, completing the VI. or pulmonary arch. Some trace of this condition appeared upon most of the individuals examined. In one case shown (Fig. 3), the injection filled only the dorsal and ventral ends of the ductus, the middle region remaining as a white cord. In the other case (Fig. 2), the pulmonary end only was injected.

Finally, in a simple diagrammatic lateral view (Fig. 4), built up on the system of Rathke's diagrams, as improved by Boas ('87), I have indicated the chief neck-arteries of the Crocodilia. In this diagram, the usually occurring arteries are drawn in heavy lines; those occurring less regularly or abnormally, in fine lines; those absent, in dotted lines. I have introduced as the II. arch the anastomosis between 1^{c} and 2 (Fig. 1), thus adopting van Bemmelen's ('88, p. 115) suggestion; but I must repeat his caution, that this is only a rather probable, but by no means demonstrated homology.

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EXPLANATION OF FIGURES

ABBREVIATIONS.

ao.	Aorta.	*ad mu. lar.*	To muscles of larynx.
art. pul.	Pulmonary artery.	*mu. pct.*	Pectoral muscles.
dt. Bot.	Ductus Botalli.	*œ.*	Œsophagus.
ad œ.	To œsophagus.	*tr.*	Trachea.

a. Left arteria anonyma, Rathke = ventral distributing trunk between IV. and III. arterial arches.

b. Right ditto.

1. Arteria subvertebralis colli, Rathke = a. carotis dorsalis, Mackay = third arterial arch and dorsal collecting trunk anterior to III. arch. In this vessel three regions may be distinguished: —

1^a. Left vessel of the posterior paired portion, the fellow of which on the right side (1^a) is usually lost, but in Figure 1 persists.

$1^b + 1^{b'}$. Fused portion of 1. (The leader should be continued to the vessel covered by the œsophagus in Fig. 1.)

1^c. Left vessel of anterior paired (unfused) portion.

2. Left collateralis colli, Rathke = a. carotis ventralis, Mackay = ventral distributing trunk anterior to III. arch.

2'. Right ditto.

3. Left a. subclavia = secondary or persistent subclavian (cf. Mackay).

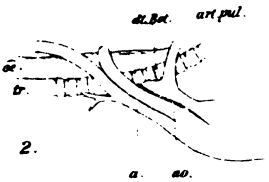
* Anastomosing branch between 1^c and 2 (= II. arterial arch ?).

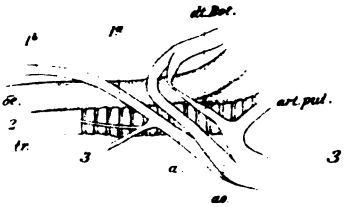
Fig. 1. Ventral aspect of head and neck regions of Alligator Mississippiensis, 28 cm. long. Part of the œsophagus and trachea are represented lying above (ventral to) the median artery.

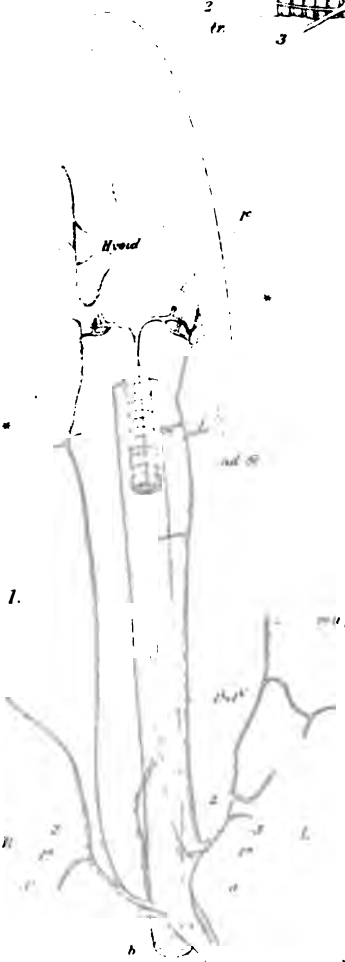
Figs. 2 and 3. Lateral views of the arterial arches to show two cases of persistent ductus Botalli.

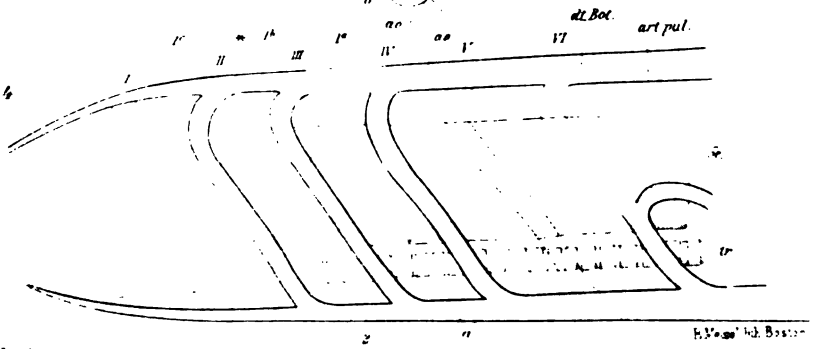
Fig. 4. Diagram, showing in side view the relation of the arterial arches of Crocodilia to the type. Heavy lines represent normal vessels, lighter lines, abnormally occurring vessels, dotted lines, vessels wholly absent in adult.

AVENPORT - CAROTIDS OF ALLIGATOR









Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

VOL. XXIV. No. 3.

ON THE EYES, THE INTEGUMENTARY SENSE PAPILLÆ, AND THE INTEGUMENT OF THE SAN DIEGO BLIND FISH (TYPHLOGOBIUS CALIFORNIENSIS, STEINDACHNER).

BY W. E. RITTER.

WITH FOUR PLATES.

CAMBRIDGE, U. S. A.:

PRINTED FOR THE MUSEUM.

APRIL, 1893.

No. 3. — *On the Eyes, the Integumentary Sense Papillæ, and the Integument of the San Diego Blind Fish* (*Typhlogobius californiensis*, Steindachner). By W. E. RITTER.[1]

THE work the results of which are embodied in the present paper was begun and well advanced at Harvard University, and has been completed at the University of California.

I wish here to express my warmest appreciation of the many kindnesses received at the hands of Prof. E. L. Mark, not only during my residence in Cambridge as a student under him, but particularly since leaving there. I have also to thank Prof. C. H. Eigenmann both for specimens sent me from San Diego while I was working in Cambridge, and for valuable information and suggestions about collecting the fish during my visit to San Diego last summer.

Typhlogobius californiensis was first described by Dr. Franz Steindachner. The species is the type of the genus, and thus far is the only one known. Steindachner's ('79, pp. 142, 143) description of the eyes is as follows: "Die winzig kleinen, wie Punkte durchschimmerenden Augen, liegen hoch am Seitenabfalle des Kopfes gegen Ende des ersten Viertels der Kopflänge; ihre Entfernung von einander steht der Schnauzenlänge nach und beträgt circa $\frac{1}{8}$ der Kopflänge." According to this author the genus resembles Crystallogobius, Gill, from which it differs in its dentition and abortive eyes.

Miss Rosa Smith ('81, pp. 19–21), — now Mrs. C. H. Eigenmann, — unaware that the fish had been described by Steindachner, redescribed it, making for it, as the Vienna ichthyologist had done, a new genus, the name of which was derived from the rudimentary condition of its eyes. *Othonops* was the generic name given it by Miss Smith, and this term, signifying as it does "veiled or obscured eyes," is, so far at least as the younger individuals are concerned, undoubtedly more nearly true to the facts, as the sequel will show, than is the name chosen by Steindachner, *Typhlogobius* signifying "blind goby." The specific name chosen by Miss Smith was *eos*. She says: "This species is most closely related to

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXV.

Crystallogobius nilssoni (Düb. & Ker.) Gill (*Gobiosoma nilssoni* Günther, Cat. Fishes Brit. Mus., III. 86), a species found on the coast of Norway, from which it is distinguished generically by the obsolete eyes. . . . The eyes are large and conspicuous in *C. nilssoni*."

With reference to the integument of the head and its tactile organs, this author says: "On the under side of the head the skin (in a preserved specimen) lies in irregular folds, which conform generally to the outlines of the lower jaw, the outer folds reaching the gill openings. Between the lower lip and these folds there is a series of papillæ which has its origin a short distance behind the corner of the mouth, the series being slightly separated close behind the symphysis of the lower jaw by two small, rounded flaps. The papillæ number about fourteen on either side of the flaps. On the superior surface of the snout, extending posteriorly half as far as the termination of the maxillary, the skin is finely wrinkled, and there is on either side a conspicuous flap, which seems to conceal a nostril." The largest specimen examined by Miss Smith was 2¾ inches in length.

The same author ('90, p. 181) publishes a note made by her at San Diego, July 3, 1882, on the tenacity of life exhibited by this species, which is so characteristic of it that I quote the passage nearly entire: "Three specimens were secured and were placed alive in a two-quart tin pail along with seaweeds, polyzoa, hydroids, living mollusks, a sea-cumber, and a number of small fishes and crabs. The living forms in the pail were so crowded and so short of water that all of the fishes except the three pink blind fish had died before I reached home, the drive of twelve miles being over a hilly road for some distance. . . . When returning from La Jolla and other points along the seabeach, I have frequently carried home the tide-pool species alive in this manner, and invariably the Oligocottus analis, one of the small Cottidæ, was more tenacious of life than any of the other species. At this time, however, Oligocottus expired with the rest, leaving the blind fish to claim the honor of being the most hardy of the smaller species of the region. This species is scaleless and exceedingly slippery. I took one of these examples from the pail, when, like an eel, it slipped through my fingers into a barrel of rain water standing near, swimming around in the barrel several times. I then removed it to a clean shallow dish into which I had poured half a cupful of sea sand, together with the small amount of dirty sea water which had covered the medley of animate beings before mentioned. Typhlogobius, still active, tried to bury itself in the sand, but the dish was too shallow, and several efforts proved unavailing. . . .

It was still quite active five hours after it was removed from among the dead fishes. How much longer it may have been able to survive I do not know, as I then killed it with alcohol."

In a paper on the "Point Loma Blind Fish and its Relatives," Prof. C. H. Eigenmann ('90, pp. 65–71) has given some very interesting facts on the habits of the species, and also the only account, so far as I am aware, of some of the profound structural changes that have been induced in it by its peculiar way of living.

The fact that the fishes pass their lives under stones in crab holes, or buried in the sand, must of course have been known by every one who had collected them; but as Prof. Eigenmann has had much better opportunity to study their habits than has any one else who has written on the subject, his account is quite full, and so interesting that I reproduce a considerable portion of it.

About San Diego the fish has been found at Point Loma only; it has been taken, however, at Encenada. Its habitat is consequently, so far as known, quite limited. The crustacean in the holes of which and with which it lives is a burrowing carideoid, which has the same pink color as the fish; but while the crustacean is found throughout the entire bay region, the fish is its companion only at Point Loma. Another species of the Gobiidæ, belonging to the genus Clevelandia, also frequents the holes of the same crustacean along with Typhlogobius.[1]

"Sometimes the fishes [other than the blind fishes?] live quite out of water on the damp gravel and sand under rocks. . . . In the bay the gobies habitually live out of the holes, into which they descend only when they are frightened, while at Point Loma they never leave their subterranean abode, and to this fact we must attribute their present condition."

It is not the eyes alone that have undergone modification. The whole frontal region of the skull has been profoundly changed; the scales have entirely disappeared, the color has been reduced, and the spinous dorsal has been greatly diminished in size. "The skin, and especially that of the head, has become highly sensitized."

[1] I find Clevelandia in San Francisco Bay at West Berkeley; and here it often enters holes in the mud with a species of Crangon. In this case the holes are not, I think, dug by the crustacean. The general appearance and actions of the two animals are so similar that at a little distance it is very easy to mistake the one for the other. The color of the two is absolutely indistinguishable as they rest at the bottom of the shallow tide-pools; and it is so like the dark brown mud of the bottom on which the animals are found that it is with great difficulty that they are seen when not in motion.

In a specimen about 0.9 of an inch long the color cells were well formed, and the membranes of the fins were thin (in the adult the fins are very thick in proportion to their height). The movements of the fish at this age were similar to those of the other gobies, and not at all sluggish, like those of the adult. In the adult, says Eigenmann, "the color has been reduced."

The eyes have suffered the greatest change of all. In the small specimen just mentioned they were quite evident, and apparently functional. "Objects thrust in front of them are always perceived, but the field of vision is quite limited. With age the skin over the eyes thickens, and they are scarcely evident externally. As far as I could determine they do not see at this time, and certainly detect their food chiefly, if not altogether, by the sense of touch."

"The lens is large in proportion to the size of the eye, which does not materially differ in size in the smallest and largest specimens examined. The optic nerve is slender and long as compared with that of any of the other gobies." Because of lack of facilities for histological work, Prof. Eigenmann did not study the minute structure of the eyes. All his attempts to get material for studying the development were unsuccessful, though artificial fertilization was tried, and many visits were made to Point Loma in search of eggs and embryos. The spawning time is June and the latter part of May.

During the last of June and the first of July, 1891, I was able to spend several days at San Diego, but at that time it was impossible to get specimens of the blind fish, a thing which I had greatly hoped to do. From Dr. Eigenmann's experiences I had thought it quite possible that at this time I might also be so fortunate as to get embryonic material of the species. On arriving at San Diego my hopes were at once annihilated, however, as I found that the fish could be caught only at the very low tides, and at this time of the year these tides come in the night. I arranged, however, with two local collectors, Mr. L. C. Bragg and Mr. O. N. Sanford, to have all the specimens they could obtain, as soon as the tides would permit of their being collected, sent to me at Berkeley. By this means I secured twenty-two specimens, the most of them apparently fully grown, though two were considerably smaller than any I had previously studied, and these were all carefully preserved in Perenyi's fluid.

Through the kindness of the officers of the Pacific Coast Steamship Company's steamer "Pomona," twelve specimens were sent to me in July from San Diego alive. Only four of these were living, however,

when they reached me, and only one was in perfect health. This one was kept in an aquarium of about four gallons of water until February 10, 1892. I can fully confirm the statements of other writers concerning the extreme tenacity of life exhibited by these fishes. During the last two months that this specimen was kept, the water was not changed nor aerated in any way, nor was food given to the fish; and I may say that it did not, so far as I could determine, take food at all during the time of its confinement, except the small quantity naturally contained in the water. Worms were placed in the aquarium, but had to be removed, untouched so far as I could see, to prevent contamination of the water by decomposition. When the fish was killed, it was to all appearance as well and as lively as it had been at any time during its captivity.

Experiments for the purpose of determining whether the eyes in this individual still performed their proper function were not very satisfactory. Very frequently when the water was suddenly illuminated by a strong light thrown into the aquarium, standing in a dark room, the fish was found to be moving about at the bottom with considerably more than its wonted activity. This activity would continue for only a short time, when the fish would either move more slowly or would settle down and become quite still. As the movements were almost always rather slow and infrequent when the fish could be seen, I am inclined to interpret this behavior as indicating that the fish was sensitive to the light. However, repeated attempts to produce conditions that would cause it to choose between light and darkness, if it had the power of such choice, were without positive results. On the whole, both from these observations on the living fish, and from the structural conditions to be hereafter described, I am of the opinion that the power of perceiving light is not wholly lost, even in the adult. The specimen kept alive was 32 mm. long, or about 20 mm. shorter than the largest ones that I have seen.

The pink color mentioned by all those who have written of this fish is a quite striking feature in its general appearance. It is not at all due to pigment in the integument, but to the extreme richness of blood-vessels situated in the sub-epidermal connective tissue, as will be shown later. It disappears entirely in preserved specimens, the color becoming a dull opaque white, particularly in large individuals. In small individuals, however, the color of the dorsal side of the head and body is quite dark from the presence of brown pigment. The causes to which these different colors, under different conditions of development and treatment, are due, are of considerable significance, and I shall speak of them more

fully later on. It is not my purpose to give an account of the general structure of the fish in this paper. I must, however, call attention to the far reaching modifications that have been brought about by its peculiar habits, not in the eyes merely, but in many other structures. As already mentioned, Dr. Eigenmann has shown that the "entire frontal region of the skull has been profoundly changed." He has also shown that the fins of the adult are much thicker, more fleshy, and shorter, in proportion to the size of the body, than in the young. My observations fully confirm these statements.

In the smallest specimens that I have seen, 19 mm. long, the eyes are distinctly visible without dissection. In some of the preserved specimens of this and somewhat larger size, the lens is also clearly seen in surface views; while in other specimens it is not so distinct, and in some is scarcely seen at all, though it is probably always present in all these younger individuals.

The eyes are situated wholly on the dorsal aspect of the head, and very near together (Plate I. Figs. 1, 2). Their distance backward from the tip of the nose is also short as compared with the length of the fish. Thus in the specimens 19 mm. long this distance was 0.95 mm., or one twentieth of the entire length of the fish. In large individuals, especially while living, the eyes are visible from the surface, but appear as scarcely more than black specks deeply buried in the tissue. In many cases they cannot be seen at all in preserved specimens.

The epidermis immediately over the eyes does not differ essentially, either in the smaller or the larger individuals, from what will be described further on as existing in other portions of the dorsum and sides of the head and body. The mucous cells are present here as elsewhere, and they are as numerous and as large as in adjacent regions. The average thickness of the epidermis is 50 μ in the smallest specimens studied; 63 μ in a specimen 60 mm. long, and 76 μ in a specimen about 65 mm. long, thus showing a gradual increase in thickness with the increasing size of the animals. In the smallest specimens the sub-epidermal tissue over the eye is not differentiated into a dermal and subdermal layer. The connective tissue in this region is arranged in several strands which unite with one another at various angles, thus bounding wide spaces (Plate III. Fig. 17, *spa.*). In this specimen (Fig. 17) the space between the epidermis and the sub-epidermal tissue is quite wide, and is continuous over the entire eye, and for a considerable distance beyond. This space may be in part artificial; but even if so, the connection between the epidermis and the immediately underlying tissue

must have been exceptionally frail, since separations of this kind are rare in adjacent regions.

The thin layer of tissue next to the lens — in fact closely applied to it in many cases (Figs. 5 and 17, *crn.*) — is part of a layer that envelops the entire eye, in many places lying close upon the pigmented layer of the retina. The portion in the region of the retina is undoubtedly the sclera, and will hereafter be designated as such. The portion in the region of the lens may be regarded as representing all there is of a cornea excepting its epithelial layer; but on this subject I shall speak further presently. The strands of connective tissue that have been spoken of as intervening between the epidermis and the eye in the smaller specimens are distinctly fibrous, and contain numerous small, much flattened connective-tissue nuclei. These strands are directly continuous with the sub-epidermal connective tissue of the surrounding regions, and are not largely continuous with the sclera, though in part they are (Fig. 17 *a*).

In addition to the small flattened connective-tissue elements in these bands of connective tissue, a few much larger cells are found (*cl. con't.*). They have distinct round nuclei, and each nucleus has a nuclear membrane and a nucleolus. The membraneless cell body is drawn out into one or more processes, usually two or three, which become lost among and are apparently continuous with the fibres of the connective-tissue strands in which the cells are situated. They are probably embryonal connective-tissue cells concerned in the production of the thick layer of this tissue that intervenes between the eye and the epidermis in older specimens (Plate II. Fig. 6). In this older specimen (Fig. 6) a large number of nuclei are seen, in part immediately over the eye, and consequently in the same position as the cells regarded as embryonal connective-tissue cells in the young specimens; but they are mostly at one side of the eye (Fig. 6, *con't. tis.*), and although some of them are undoubtedly cells of connective-tissue character, at the same time many of them are certainly not of this nature, but are probably leucocytes. As shown in Figure 6, there is over the eye in the large specimens a well defined dermal layer, *drm.*, which usually remains adherent to the epidermis when the latter is removed. This layer is nearly structureless, though fine fibres are not uncommon in it. In the specimen shown in Figure 6, the entire thickness of the tissues over the eye is about 392 μ, of which 103 μ is epidermis and 289 μ sub-epidermis. About midway between the epidermis and the eye there is a thin stratum of formed connective tissue (*st. con't.*), much denser than the surrounding tissue; and imme-

diately beneath the dermal layer is a layer of comparatively coarse fibres arranged in bundles running more or less nearly parallel with one another. Among these bundles are blood-vessels and numerous cells, mostly of the kind that I have regarded as leucocytes. The remaining portion of the tissue in this region is composed of rather fine uniform fibres, containing very few cellular elements. I have said that the eye-enveloping portion of the connective-tissue capsule that is immediately over the lens probably represents the cornea, excepting its epithelial layer. When, however, we bear in mind the method of development of the cornea, — as first clearly made out by Kessler ('77, pp. 83–94), and now understood by all embryologists, excepting in so far as this author believed it to contain, besides its epithelial layer, elements derived from the ectoderm; and when we remember, further, that in the cornea of the normal adult eye, the substantia propria, together with the membrana elastica anterior and the membrane of Descemet, make up its entire thickness, excepting its conjunctival (i. e. epithelial) layer, the interesting question arises whether in such an eye as is represented in Figure 6 the layer *crn.* should be regarded as representing the whole cornea, or merely the membrane of Descemet. Should the latter interpretation be adopted, then it would follow that the tissue intervening between this and the dermal layer would be the substantia propria greatly thickened, and the dermal layer (*drm.*) would be the membrana elastica anterior of the cornea; and what I have called embryonal connective-tissue cells (Fig. 17, *cl. con't.*) might then be regarded as corneal corpuscles. However, I hardly think this the right view of the matter, since, as already pointed out, the tissue over the eye is mostly continuous with that of the adjacent regions other than the sclera. It is possible that the strands seen at *a*, Figure 17, give some support to such an interpretation. But whatever view may be taken, it seems to me that we are justified in regarding the conditions here presented as evidence against Kessler's statement that a portion of the cornea, besides its epithelial layer, is derived from the ectoderm. This author's account of the development of the cornea in Triton is in substance as follows.

The first trace of it to appear is a thin layer of hyaline substance on the inner surface of the ectoderm over the eye. This appears at a time when the cavity of the lens vesicle has wholly disappeared, and the retinal layers have begun to be differentiated. (See the author's Figure 60.) This layer is held to be secreted from the ectoderm. The succeeding steps may best be given in the writer's ('77, pp. 89, 90) own

words: "Wenn die zuerst vorhandene hyaline Schicht eine gewisse Dicke (Figg. 60 und 61) erreicht hat, wird dieselbe vom Hornblatt abgedrängt durch eine zweite an dieses sich anbildende hyaline Schicht; in das zwischen beiden Schichten entstehende Interstitium dringt von der Peripherie her eine einzellige Lage der spindelförmigen Kopfplattenelemente, die sich vorher schon in einen spitzen Winkel gegen das Hornblatt am Rand der Corneaanlage gestellt hatten, ein (Fig. 62); sobald dieselben von allen Seiten her im Pol der Cornea zusammentreffen, ist die erste hyaline Schicht von der unterdess zu der gleichen Dicke entwickelten zweiten vollständig gesondert. Ebenso wie die erste durch die zweite, wird dann die zweite durch eine dritte neu sich bildende Schicht vom Hornblatt und darauf durch eine zweite einwandernde Lage von Kopfplattenelementen von der dritten Schicht isolirt; diese wieder vom Hornblatt durch eine vierte neue Schicht und von letzterer durch eine dritte Zellenlage u. s. f." It would thus appear that a very intimate connection is brought about between the ectoderm itself, the relatively large portion of the substantia propria derived from it, and the mesodermal elements of the cornea; and it should be especially noticed that this process goes on at a comparatively late stage of development, — viz. at a time when the retinal layers are being differentiated, and after the pigmented portions of the eye are well formed; in short, at a stage only a very little earlier than that at which development is arrested in the eye of Typhlogobius. If such a process had ever taken place here, it seems almost certain that we should see some indications of it in such a stage as is shown in Figure 17 (Plate III.). But, on the contrary, what we do find is no connection between the epithelium over the eye and the immediately underlying tissue, or at least almost none, and no indication of a hyaline layer on the inner surface of the epithelium. While, on the other hand, in older specimens (Plate II. Fig. 6) the epidermis and the sub-epidermal tissue are in close connection, there being no interruptions or spaces at all, and we have here a well defined nearly structureless layer closely adherent to the epidermis.

There is considerable individual variation in the size of the eye. In three specimens, 50 mm., 60 mm., and 63 mm. long, the diameters, measured parallel to the long axis of the head, were respectively 0.44 mm., 0.46 mm., and 0.47 mm.; the diameters transverse to the long axis of the head in the last two of these were, respectively, 0.39 mm. and 0.47 mm. In another specimen 63 mm. long, the diameter transverse to the head was 0.372 mm.; the diameter parallel to the long axis of the head was not measured in this specimen. This last measurement was made on the

section, while the measurements in the case of the first three were made with the eyes in place in the head, the head having been cleared in clove oil. It is undoubtedly true, that some of the difference in size between the last mentioned eye and the first three was due to shrinkage in it during its passage through the paraffine. I have made numerous measurements of the same eyes before embedding and after cutting, and have always found the sections somewhat less in diameter than the whole eyes, even when all precautions had been taken to prevent shrinkage. But certainly shrinkage cannot account for the great difference found here between the eye measured in section, and the one of an individual of the same length measured in the head. This small eye, I should add, was the only one that I have found in which the lens was wholly absent. This eye will be described later on. In a specimen 25 mm. long the axial diameter of the eye was 0.28 mm., and its equatorial diameter was 0.45 mm. In a specimen 19 mm. long the diameter in the long axis of the head was 0.28 mm., and transverse to this it was 0.39 mm. It appears from these measurements that the eye does increase somewhat with the increase in size of the animal, though it is true that, in view of the obvious individual variation in size in specimens of nearly the same length, not enough of the smaller specimens have been studied to determine definitely how much this increase amounts to.

A sclerotic coat, well defined from the surrounding connective tissue, is always present, though in some places its fibres, both singly and in bundles, leave their concentric course and pass off into the connective tissue, and thus bring about an intimate connection between the two. In some places the connective-tissue fibres not belonging to the sclera, but in its vicinity, are seen to have taken on a concentric direction even at a considerable distance from the eye, and to have become more numerous and more closely packed than is the case with the subcutaneous connective tissue in general. There is thus brought about a fusion to some extent of the eye bulb with the tissue in which it is embedded. This statement applies especially to the eye the section of which is shown in Figure 6. In most sections numerous flattened connective-tissue cells are found in the sclera; and in all the eyes that I have sectioned the sclera is cartilaginous in the region corresponding to the ora serrata of the retina. The cartilaginous layer is usually only one cell thick, but occasionally it is two or more cells thick (Figs. 5, 6, and 12). In many specimens the cartilage does not extend entirely around the eye in the equatorial zone, and in no case have I seen it extend more than half way back to the entrance of the optic nerve. No

indication of ossification of the scleral cartilage, as is common in bony fishes, has been seen. No trace of an argentea is to be found. All the pigment is of the same dark brown granular variety, and, when seen by reflected light, never gives the white, silvery color that is characteristic of the crystalline material of the argentea.

The choroid is exceedingly rudimentary, and in many specimens I have been unable to detect its presence at all. In the eye from which Figure 13 was drawn (Fig. 13, *chr.*), — a specimen the eyes of which, as will be seen further on, are better developed in several respects than is usual in these eyes, — it is more distinctly seen than in any other case that I have studied. Here the layer of pigment is very thin; it is interrupted at short intervals, and cannot be traced for more than one third of the distance through which it would normally extend. Whether this pigment should be regarded as representing the lamina suprachoroidea, or as belonging to the choroid proper, it is impossible to say.

In a few instances (Figs. 13, 14, 15, *chr. cpl.*), a layer of cellular tissue has been found at the proximal pole of the eye, extending for a variable distance toward the anterior rim of the optic cup, but rarely reaching it. This layer is always closely applied to the outer surface of the pigmented layer of the retina, and in some sections it seems to be continuous with the pigment of the choroid. In some places (Fig. 15, *chr. cpl.*) the tissue has very much the nature of formed connective tissue, while in other places (Figs. 13 and 14, *chr. cpl.*) the cells are spherical or elliptical, with indications at times of blunt processes, and with distinct nuclei. Where cells of this kind occur, the layer is somewhat thicker than where the structure is more characteristically that of connective tissue; and in several instances blood corpuscles (Fig. 13, *cp. sng.*) are found scattered here and there in these thicker portions of the layer, indicating the presence of capillaries. I identify this layer as the chorio-capillaris.

A conspicuous structure in all the specimens studied is a thick, usually short, somewhat lenticular mass of pigment occupying a position usually at the proximal pole of the eye, at or near the entrance of the optic nerve, by which it is pierced in some cases (Figs. 14, 15, etc., *gl. chr.*). This mass is concentric with the surface of the retina, but is always separated from it by a short though somewhat variable interval. In some places the cellular layer just described in part occupies this space, and in some places the thin layer of choroid pigment is seen to enter the same space. The mass always lies within the sclerotic, and is always composed entirely of pigment. I have been unable to find any cellular or other protoplasmic elements in it. This body I interpret

as representing the "choroid gland." The evidence for this is principally in the position which it occupies, and very little in its structure. It is true that this body may contain a small amount of pigment in the normal eye, as I find to be the case in Clevelandia, yet its characteristic structure consists, as is well known, in its richness in blood-vessels; but, as already said, none of these occur in Typhlogobius. Its position — viz. at the proximal pole of the eye at or very near the entrance of the optic nerve, and between the chorio-capillaris and the sclerotic — is, however, strong evidence in favor of regarding it as the "choroid gland." This structure is described in text-books (Wiedersheim, '86, p. 412) as being situated in the normal fish eye between the argentea and the pigmented layer of the choroid. The fact that no argentea is present in the eye of Typhlogobius weakens somewhat the force of the evidence that I have used to support the assumption that I have made with reference to the significance of the pigment mass described. But its relation to the chorio-capillaris and the pigment layer of the choroid are the same as that of the "choroid gland"; as is also its relation to the sclera, with the exception that no argentea is interposed between the two. Of course it is impossible to say that, were the argentea developed, it would lie between the sclera and the pigment mass, rather than between the latter and the pigmented layer of the choroid. We however have as much reason to suppose it would occupy the former position as the latter.

The pigment layer of the retina is exceedingly thick. In a specimen about 50 mm. long, the entire thickness of the retina including the pigment layer was 0.108 mm., and that of the pigment layer was 0.07 mm.; while in a specimen of Clevelandia of about the same length, the entire thickness of the retina including the pigment layer being 0.13 mm., the thickness of the pigment layer was only 0.037 mm.; that is, in Typhlogobius the thickness of the whole retina is to the thickness of the pigment layer as 1.5 : 1, while in Clevelandia the corresponding ratio is 3.5 : 1. In Gasterosteus, I find that about the same proportion holds as in Clevelandia, whereas in the perch (H. Müller, '57) the proportion is at least not less, and in the salmon a year old (Hoffmann, '83) the proportion is 6+ : 1.

The layer is composed wholly of pigment of the dark brown granular variety. I have searched in vain for cellular elements within it. In most specimens the pigment is a very uniform mass; but occasionally one finds an eye in which very distinct and perfectly round nodules of pigment occur. Some of these are so clear-cut and smooth in outline that they have the appearance of perfectly round cells wholly trans-

formed into pigment, though they are considerably larger than any cells, even blood corpuscles, that are found in the eye (Plate II. Fig. 13, *glb. pig.*). They probably merely signify that the pigment tends to segregate in such nodules during its formation. On the inner surface processes of pigment project down among the rods, as in normal eyes, excepting that in most instances they are relatively much shorter and less distinct; in some specimens they scarcely appear at all (Plate II., Figs. 5 and 13 *pr'c.*). The greater portion of the thickness of the layer pertains to the region between the bases of these processes, i. e. the terminals of the rods, and the outer surface of the layer. And it is hence in this portion that the increase in thickness over that found in normal eyes has taken place; for in the latter, this region is relatively thin. I am at a loss to know from what source this pigment has come. As already said, no cellular elements are to be found in the layer, so it is quite certain that they have completely degenerated into pigment. I shall return to this question in the comparative part. The layer thins out rapidly as it approaches the ora serrata, and is frequently thrown into an equatorially directed fold (Plate II. Figs. 5 and 13, *), which may extend entirely around the eye, but more commonly is confined to one side of it.

Immediately in front of the thinned out region just mentioned, the pigment thickens again somewhat, to form the pigmented portion of the iris. This structure, though always present, varies greatly both in form and size. In a majority of specimens the pigmented portion constitutes the entire iris; and in all cases it forms by far the greater portion of it. The dense pigment is entirely the same in structure as that in the pigment layer of the retina. In the few cases where a cellular portion is present, it is in small quantity, and appears to be of the nature of connective-tissue cells and fibres. Neither blood capillaries nor epithelium have been detected in this region (Figs. 5, 13, and 17, *ir.*). It frequently happens that the outer surface of the iris is in contact with the inner surface of the cornea (see figures), and it is thus made to appear as though the iris has a considerable part in addition to its pigment; this, however, is undoubtedly only an appearance caused by the inner border of the iris having been thrust outward by some artificial means, — probably by the lens being in most cases moved outward, for this body is very loosely held in its place. In a few specimens a trace of the ligamentum pectinatum is present, though in most cases no trace of it exists. The short blunt processes of pigment occasionally seen projecting toward the lens (Plate III. Fig. 17, β) remind one of the ciliary

processes, but it is extremely doubtful if they should be so interpreted. They are situated too far from the ora serrata and too near the free edge of the iris. They are probably in some way merely incidental to the extensive pigmentation of the iris.

In no instance are the layers of the retina in Typhlogobius as fully differentiated as in the normal eyes of fishes. I will first describe them as they are found in the majority of specimens, beginning with the innermost layer, and will afterwards speak of the cases that show deviations from the common condition.

An internal limiting membrane, distinct from the layer of nerve fibres, I have been unable to find. Corresponding with the exceedingly rudimentary condition of the optic nerve, the layer of nerve fibres is very thin, even in the immediate vicinity of its entrance, where, in the normal retina, it reaches its greatest thickness. In many sections only fragments of it are to be seen; and for considerable areas no traces at all are found. It is possible that its absence is due to its having been broken away during the preparation of the sections; but, however that may be, it is certain that, wherever present, the layer is very thin (Plate II. Fig. 5, Plate III. Figs. 18 and 21, *st. fbr. opt.*). The next layer, viz. that of the ganglion cells (Figs. 18 and 21, *cl. gn.*), is always distinct, and is from one to three or four cells in thickness. As a rule only the nuclei are distinguishable; but occasionally the cell bodies can be made out. Examined under high powers and with careful focusing, some of these are found to possess one or more processes (Fig. 18, *cl. gn.'*). A nuclear membrane can usually be seen, as can also one to several darkly stained particles within the nuclei. The nuclei are in general very nearly spherical, though there is a tendency for them to become elliptical with the longer axis radially directed.

The inner reticular layer (*st. rtl. i.*) is well developed in all cases, and is essentially the same in structure as in the normal eye, though I have not detected any of the fibres running parallel with the surface of the retina that are found in normal fish eyes. Within this layer the radial fibres of Müller (*fbr. Mü.*) can usually be made out, though they appear to be few and indistinct.

The remaining portion of the retina, as far as to the external limiting membrane, is never fully differentiated into the layers that are found in the normal eye between this membrane and the inner reticular layer; and in many specimens scarcely any indication of a differentiation can be seen. About the average condition is shown in Figure 18, *st. rtn.'*, where a layer of nuclei (*st. nl. i.*) about two or three deep may be dis-

tinguished next to the inner reticular layer. These are slightly larger, on the average, than are the more superficially situated nuclei (*st. nl. ex.*), and they also stain somewhat more deeply. Usually each nucleus has a centrally placed nucleolus, and a not very distinct nuclear membrane. These nuclei undoubtedly represent the inner nuclear layer, though whether the entire layer or only its spongioblasts, it is impossible to say.

Following this layer there is usually a single layer of nuclei (*st. rtl. ex.*) that are considerably smaller and less distinct than those of the layer last described. Not only are the nuclei themselves here smaller and less distinct than those of the layers on either side of them, but spaces (*st. rtl. ex.'*) are seen at intervals in which there are no nuclei at all. It seems quite certain that the outer reticular layer is represented by these spaces.

Finally, outside of this layer follows another of nuclei about one or two deep (*st. nl. ex.*) that are again somewhat larger and more distinctly stained than those in the layer last described. No difference between them and those of the inner nuclear layer can be discovered, excepting, as said above, that they are slightly smaller, and stain a little less deeply. They are undoubtedly the nuclei of the rods, i. e. the outer nuclear layer, though I have been unable to trace a connection between them and the rods, and it is somewhat surprising that they are slightly greater in diameter than the rods.

The external limiting membrane (*mb. lim. ex.*) is usually quite distinct.

The rods are well — probably normally — developed, but I have searched in vain for cones. In the retina shown in Figure 18, they are quite variable both in length and diameter, being in a few instances knobbed at the outer ends (*bac. cla.*). It is, however, quite possible that both this appearance and the shortness of some of them are due to artificial causes, but the variation in diameter could scarcely be so explained.

With a single exception, to be described more minutely hereafter, the lens has been present in all the specimens studied in detail.

It differs in no way in structure from the lens in normal fish eyes that I have examined; i. e. it appears entirely homogeneous and structureless after preservation in alcohol, Perenyi's fluid, or picro-nitric acid. It is held in position very loosely, and consequently is easily displaced; it is frequently found, in prepared specimens of the eye, pushed entirely out of its proper situation into the somewhat yielding connective tissue

which lies immediately over it. No trace of a suspensory ligament seems to be present, nor have I been able to find a processus falciformis.

In a single instance, viz. in the eye portions of which are shown in Figures 13 and 21, and which has already been spoken of as showing in several respects a higher state of development than any other specimen studied, I find close behind the iris, within the cavity of the eye, a few strands of tissue containing a few small nuclei, which may possibly be regarded as the hyaloid membrane, though I do not feel at all certain that this is their nature. In the same specimen a very few blood corpuscles are also found close behind the lens within the eye chamber. With this single exception I have been unable to find a trace of tissue within the chamber.

The optic nerve, although exceedingly slender, is always present, so far as my observations have gone. A very striking fact in connection with it is the thick sheath of pigment that surrounds it in its passage through the retina (Figs 6, 13, and 15, *pig.'''*). This sheath invests the nerve very closely, no space existing between it and the latter; however, in its course through the retina, a considerable non-pigmented space is sometimes seen between its outer surface and the pigment of the retina; indeed, in a majority of cases the outer boundary of the sheath can be traced entirely through the retinal pigment.

These facts make me incline to the opinion that this sheath really belongs to the nerve, and has arisen by the pigmentation of the outer portions of it. The fact that in many cases it continues on without interruption through the cellular portion of the retina, nearly to its inner surface (Plate II. Figs. 6 and 13), gives considerable confirmation to this view. It would seem, however, were this the right interpretation, that we should find a rather more gradual disappearance of the pigment in passing, on a section, from the main mass of the wall of the sheath to the unpigmented portion of the nerve, than we do; but the inner surface of the sheath is not quite as sharply defined as its outer surface is.

On account of the position of the eyes, far anterior to the brain, and near the anterior extremity of the head, the optic nerves are very long.

The muscles of the eyeballs (Fig. 8) are also very long and slender, and are probably always present, though I have not been able to detect them in the sections in all cases; but in eyes dissected out and cleared in glycerine or clove oil, or slightly stained in Schneider's acetic acid carmine, I have always found them. Figure 8 is a camera drawing from a glycerine preparation, showing all the muscles excepting the internal oblique, and also the nerve.

I will now describe certain eyes that present exceptions to the conditions already described. The first will be the eye that shows the maximum development; the second, eyes that show the minimum development and the maximum degeneration.

The specimen that shows the greatest development has already been mentioned (page 61) in connection with the choroid and the hyaloid membrane, and the reader is referred to the statements there made concerning these structures.

The most interesting evidence of unusual development is found in the greater differentiation of the layers of the retina; and it is in the greater distinctness of the outer nuclear (*st. nl. ex.*) and outer reticular (*st. rtl. ex.*) layers that the difference chiefly consists (Fig. 21). Whereas the former is ordinarily, as in Figure 18, only one or two cells thick, (exclusive of the cells *st. rtl. ex.*), in this instance it is three or four cells thick; but more significant than its greater thickness is the fact that the deepest cells (*nl. ba.*) are arranged in a regular layer one cell thick, and closely packed.

What this layer of nuclei represents will be pointed out in the comparative part; it may be said here, however, that it probably does *not* belong to the outer nuclear layer. Although the external reticular layer even here does not present a well defined boundary either internally or externally, — particularly not internally, — the irregular areas which have already been mentioned as being destitute of nuclei in the average specimens (Fig. 18, *st. rtl. ex.'*) are here considerably more distinct (Fig. 21, *st. rtl. ex.*), both as to thickness and frequency of occurrence. In fact, the layer may be regarded as having the characteristic structure of the normal eye, excepting that it contains a considerable number of scattered nuclei, and is without distinct limitation internally. The rods also seem to be better developed in this specimen than in others. In many of them what has the appearance of an indistinct structureless nucleus may be seen occupying the extremity of the fourth of the rod nearest the external limiting membrane (Plate IV. Fig. 22, *a* and *b*). This one fourth probably represents the inner member of the rod. In some cases the nuclear-looking structure terminates on the side directed toward the distal end of the rod with a well defined straight line, but in other cases the whole has a round or elliptical form. This portion of the rod takes stain slightly, but it is the only portion that does. The substance of the remaining portion is uniformly opaque-glassy in appearance, excepting that numerous pellucid spots exist in it. These are considerably more distinct in some rods than in others, and occasionally

they form a regular row through the whole length of the outer member (Fig. 22, *c*). They are mostly confined to the outer members, but in some rods a single one of unusual distinctness is found in the inner member.

I now pass to the least developed and most degenerate eyes. Perhaps the specimen most interesting in this respect is the one shown in Figure 6. In this the lens is entirely absent, a continuation of the pigment layer of the retina extending without break entirely over the space that this structure should occupy. The series of sections of this eye is complete, and every section is as perfect as the one from which Figure 6 was drawn; so there can be no possibility that the absence of the lens is due to artificial causes, or that an error in observation has been madé. I should add, also, that I have an equally complete series of sections of the other eye of the same individual, and this shows the same structure in every particular. Over a portion of the outer moiety, the pigment is disposed in a double layer (Fig. 7, *pig.'* and *pig.''*). The outer of these layers is more directly continuous, both in thickness and direction, with the pigment layer of the retina. The inner layer presents a considerably thickened mass, *pig.''*, irregularly lenticular in form. From the appearance shown in this figure, one is tempted to regard this pigment mass as a remnant of the lens, the thinner portion of the layer at its edges, which connects it with the pigment layer of the retina, representing the iris. It is very doubtful, however, if such is the case. With such an interpretation the outer pigment layer (*pig.'*) would seem to represent the inner layer of the cornea; and this would afford an explanation, not obvious otherwise, of the continuity of the layer over the pupil. But there are several difficulties in the way of these convenient interpretations. In the first place, the pigment mass under consideration is found on examining the entire series of sections to be very irregular in form, and, as shown in Figure 6, to become confluent with the outer pigment layer (*pig.'*) in some portions of the eye; in the second place, as is shown in the figures, and has already been mentioned, the outer layer is directly continuous with the pigment layer of the retina, which of course it should not be if it belongs to the cornea; and, in the third place, the inner layer of the cornea is itself present and not pigmented (Figs. 6 and 7, *crn.*).

Concerning the condition of the retina in this eye I speak with considerable hesitation, because of a fear that its peculiarities may be due to artificial causes. I should say, however, that the specimen was hardened in chromic acid, and that all the tissues around the eye are well

preserved. If the retina is macerated, it is because the preserving fluid failed to penetrate through the pigment layer in which it is wholly incased. Consequently, I shall not dwell at length on the subject, nor insist much on the significance of the structure described. Figure 19 is a rather highly magnified view of a meridional section of the retina near the ora serrata. It will be seen that only the layer of ganglion cells, the inner reticular layer, and undifferentiated layer are here distinguished. The inner reticular layer does not differ from that found in ordinary eyes. But with the other layers the case is quite different. The nuclei are much less closely packed than in other eyes, the intervening spaces being occupied by a few scattered fibres. The nuclei appear to be of two quite distinct kinds. One kind (*leu'cy.*) is somewhat larger than the other, stains considerably less deeply, is less refractive, and shows no trace of a membrane. In the other kind, the nuclei are smaller, *cl.*, *cl.'*, *cl.''*, stain deeply, and are refractive in such a way that in focusing through them they take on the three different appearances shown in the figure; i. e. when seen at a high focus they appear uniformly dark, as at *cl.*; at a deeper focus the appearance is that of a disk with a dark line at its circumference, a light yellow zone (represented in white in the figure) inside of this, and a uniformly dark spot in the centre, *cl.*; at a still deeper focus the appearance is that of a dark ring with a light centre, *cl.''* A few of these latter have two or three longer or shorter processes, but by far the larger number of them are spherical, or nearly so.

No rods are present in these eyes, though this portion of the retina is so ragged and formless that it is impossible to say whether they have ever been developed or not. It is quite possible that the larger bodies, in which, however, no nuclei are visible, are leucocytes.

Another interesting exceptional case is that presented by the section of the eye shown in Figure 12. It will at once be seen that the point of chief interest lies in the double layer of pigment that is situated behind the lens within the cavity of the eye. The outermost of these layers is in close contact with the posterior surface of the lens, while the innermost is in close contact with the inner surface of the retina. I cannot, however, satisfy myself that either layer is developed at the expense of the parts to which they are respectively adjacent. It is true that the line of contact between the lens and its pigment layer is not a sharp one, there evidently being a gradual disappearance of the pigment here. The lens, however, shows no flattening on this side, as it would were the pigment layer formed at its expense; but more than this, the

pigment layer extends on either side beyond the lens, its outer edge becoming on one side (the lower one in the figure) continuous with the inner layer of pigment, and on the other side with the pigment layer of the retina. The connection with the outer is shown rather indistinctly in the section figured, but much more distinctly in some of the other sections of the series, as is also the fact that at places the iris is entirely cut off from the retinal pigment. If, then, these layers of pigment have come neither from the lens nor the retina, the only other structures in this region that they could come from are the vitreous body and the hyaloid membrane. In other respects this eye does not differ appreciably from the usual structure already described, with this exception, that the undifferentiated layer of the retina shows somewhat less differentiation than usual. I have studied these sections in vain to find convincing evidence of actual degeneration within the retinal elements themselves, in addition to the pigmentation.

I now present a table showing some of the results of measurements that have been made of the retina, lens, and optic nerve: —

	Two Specimens, each 19mm. long.		Spec. 50mm. long.	Spec. 60mm. long [1]	Spec of Cleveland.
	1	2	3	4	5
	mm.	mm.	mm	mm.	mm
Entire retina (including pigment layer)	.095	.075	.110	.145	.136
Pigment layer	.055	.046	.063	.078	.042
Nerve fibre layer	.0029	.0014	.0043	.0058	.05
Ganglion cell layer	.004	.0029	.0072	.0058	.05
Inner reticular layer	.013	.0058	.0116	.018	.021
Undifferentiated layer	.017	.001	.0203	.0317	
"Undifferentiated layer" of Nos. 1, 2, and 3:					
Outer nuclear layer				.0058	.016
Basal nuclei in outer nuclear layer				.0029	.0029
Inner nuclear layer (including outer reticular layer)				.0023	
Outer reticular layer					.0018
Tangential cell layer					.0029
Inner nuclear layer					.029
Diameter of lens		.205			.784
Thickness of optic nerve at entrance to retina				.011	.117
Length of rods				.032	

Perhaps the most important thing that these measurements reveal is the fact that the eyes are subject to great variation, as well in the pro-

[1] The same specimen from which Figures 13 and 21 were drawn.

portion of their constituent parts as in their size and degree of differentiation in different individuals.

It is quite probable that some of the differences in thickness between the retinas of different individuals is due to the fact that measurements have been made on sections not quite meridional in direction. Care has been taken, however, in each instance to avoid this source of error. But in the case of the one giving a thickness 0.145 mm. greater than that of the normal retina in Clevelandia, the sections are so cut that none are quite meridional. As may be gathered from Figure 13, this eye is so flattened in its axial direction that the retina is almost disk-shaped; and from this fact it was possible so to cut the retina that none of the sections would be entirely perpendicular to its surface. The sections *are* so cut obliquely, though the deviation from the perpendicular is certainly not sufficient to account for the great difference in thickness that is shown. But the difference in proportion between corresponding layers in different retinas cannot be explained, even in part, as due to artificial causes. In one of the specimens 19 mm. long, the ratio between the inner reticular layer and the whole retina is 1 : 7, while in the other it is 1 : 13.

From the measurements here given alone, it might be concluded that there is a gradual increase in thickness, and a constantly advancing differentiation in the retina, with increase in the size and age of the animals. Such a conclusion is not warranted, however, when the whole number of specimens and stages that have been studied by me is considered, though it must be admitted that, in view of the obviously wide range of individual variation, the number of specimens examined has not been sufficiently large to justify an unqualified denial that such is the case. All that can be said with positiveness is, that, notwithstanding the fact that the thickest and most fully differentiated retina has been found in a specimen much larger — and therefore presumably older — than the smallest studied, yet several still larger individuals have shown retinas thinner and less differentiated than those of the smallest individuals; and, further, that in one instance at least one of the smallest individuals shows in the distinctness of the outer reticular layer as great a degree of differentiation as any retina examined. It would be a very interesting and significant thing, if, owing to a retardation in development, differentiation of the retina should continue throughout the entire life of these fishes; since we know quite well that normally the fish eye becomes functional and differentiated at an early period in development (Balfour and Parker, '82, pp. 371 and 384; Ryder, '84, p. 500; Hoffmann, '83).

It is exceedingly desirable to ascertain what law, if any, controls the

variations of functionless organs. Having now before us the facts relating to the structure of the eye, we may pass to some reflections on their significance when considered from a comparative and a developmental point of view.

First of all, I will speak of the pigment layer of the retina. This has the greater interest since, according to R. Wright (Wiedersheim, '86, p. 427), in the retina of the "blind fish Chologaster papilliferus there is no pigmented epithelium."

It has already been shown that in Typhlogobius this layer is always thicker, relatively, than in the normal fish eye, being thicker than the entire remaining portion of the retina. I am in considerable doubt as to how this thickenning has taken place. The first explanation that suggested itself to me was that the choroid had become wholly converted into pigment and fused with the pigment lamella of the retina. However, the dense and uninterrupted character of the pigment of the layer, and the evenness of its external surface, at once threw grave doubts in the way of this explanation, and the more because of the rather meagre development of the choroid in the normal eye of bony fishes. Then, as the choroid was found on further study to be present outside of this layer, the only remaining alternative was to suppose the latter to be wholly derived from the proximal wall of the primitive optic vesicle; i. e. to represent the pigment lamella of the retina. We may possibly suppose that the proximal wall of the primitive optic vesicle never became thinned out as it does in normally developing eyes; but the fact that this process takes place very early — in bony fishes, at least, by the time the differentiation of the retina has begun — is quite a serious objection to such a supposition. But even if this were the case, it is hardly possible to believe that this layer was ever as thick as we find the pigment layer in the adult fish to be. We seem forced to suppose that for some reason the layer has actually increased in thickness concomitantly with the retardation in the development of the eye, or, it is quite possible, with the *degeneration* of this particular part of it.

I would call attention to the comparison of Typhlogobius with Clevelandia in this regard. From the figure of the retina of the latter, it will be seen that the retinal pigment appears in two quite well marked layers, an outer and an inner, the two being connected at short but somewhat irregular intervals by crossbeams or processes (Fig. 20, *cr.*, *i.*, and *m.*). From this it seems that the inner extremities of the processes of the retinal pigment layer, which in normal eyes, and particularly in many teleostean eyes, project far down among the rods and

cones, have here become fused together to form a continuous inner layer, *i*.

So far as I have been able to determine, this condition is peculiar to Clevelandia, at least to the extent in which it is here seen. The interesting question now arises whether we have here the beginning of a process that would, under conditions that have brought about the changes seen in the Typhlogobius retina, ultimately result in a similar thick, solid retinal pigment layer; this being effected by a still further fusion of the cross rods of pigment now seen. As already pointed out, it is certain, both from Dr. Eigenmann's observations and my own, that Clevelandia spends some time at least in holes in the ground.[1]

The only doubt existing concerning the identification of the layers of the retina is with reference to what I have called the outer reticular layer (Plate III. Figs. 18 and 21, *st. rtl. ex.*), and the layer of nuclei (Fig. 21, *nl. ba.*) that has been designated by the non-committal term of "basal nuclei," *basal*, i. e., with reference to the outer nuclear layer. On comparing Figure 21 with Figure 20, the section of a Clevelandia retina, there will be little doubt of the correspondence of layer *nl. ba.* in the two cases; but at the same time the entire absence of layer *ful.* (Fig. 20) will be noticed in Figure 21. These two layers together seem to correspond to W. Müller's ('74, pp. 60 and 61, Taf. XIII. Figs. 4 and 7) layer of tangential fulcrum cells. This layer is described by this author as being composed in Petromyzon of "zwei Etagen grosser quadratischer Zellen, zwischen welchen eine Schicht ganz flacher, in faserartige Ausläufer sich fortsetzender Zellen gelagert ist." The layer is said, in the same connection, to be subject to much modification in the different families of fishes, in which alone it is well developed; but the Percidæ and the Cyprinidæ are mentioned as teleostean groups in which the layer with both its "Etagen" is present. According to this interpretation the external granular layer of M. Schultze, called in this paper the external reticular layer and by Krause ('76) the membrana fenestrata, is not present in either Clevelandia or Typhlogobius; and it is instructive to note that Krause does not find this

[1] I may here add an observation recently made, which indicates that the time thus passed hidden from the light is not inconsiderable. On some of my visits to the beach at West Berkeley I have found the fish very numerous in the tide-pools, while at other times hardly any are seen. Whether their absence is due entirely to their having gone into the holes I am not sure; but however that may be, at such times I have occasionally found them by digging. I am not yet able to say whether their disappearance is in any way correlated with conditions of the weather as regards sunshine.

layer in Perca fluviatilis. Its position would be between the external nuclear layer and the layer *nl. ba.* (Figs. 20 and 21). The outer of the two "Etagen" of Müller's tangential fulcrum cells appears to correspond to Krause's membrana perforata, and likewise to M. Schultze's basal plexus, and the inner to Krause's stratum lacunosum; this would make the layers *nl. ba.* and *st. rtl. ex.* of the Typhlogobinus retina the membrana perforata and the stratum lacunosum, respectively. An objection to this interpretation is possibly presented by Hoffmann's account of the development of the Salmon retina. His Figures 10, 11, and 12 (Taf. V.) show that what he calls the tangential fulcrum cells become differentiated quite early, certainly as early as the stage of development represented by the partially developed retina of the adult Typhlogobius. But judging from the position of this layer in relation to the inner nuclear layer and the layer that he regards as the outer granular layer, it would seem that his tangential fulcrum cells correspond to the inner "Etagen" only of what Müller designates by that name. But according to my interpretation these cells are not present in Typhlogobius, unless they be represented by the scattered cells in layer *st. rtl. ex.* The chief point to be made in this discussion of the homologies of the retinal layers is this. In the most differentiated retina, even though all the layers found in the normal adult fish eye may be marked out, the differentiation is much less complete as regards the zone between the two nuclear layers than it is in the normal eye of a closely related genus; while in a majority of individuals development is arrested at a considerably earlier stage.

In view of the almost universal statement that the rods and cones are the latest of all the parts of the retina to be developed, it would, I think, hardly be expected that the rods should be as complete as they are in these eyes. O. Hertwig ('90, p. 402) says, "Of all parts of the retina the remarkable rods and cones are the latest developed." Hoffmann ('83, p. 68) says, "According to all other authors [Lowe excepted] they [the external members of the rods and cones] arise latest of all the retinal elements in the different animals; and it is likewise so in bony fishes." It would certainly seem that the testimony of the eyes of Typhlogobius is against the absolute correctness of these statements.

The recent papers of Hess ('89), Kohl ('89), and Schlampp ('91 and '92) together with the somewhat older contributions to the same subject by Leydig, Kadyi, Ciaccio, and others, make possible a detailed comparison of the eyes of Typhlogobius with those of Proteus anguineus and Talpa europea.

On the whole, it appears that the eye of Proteus is more rudimentary than that of either Typhlogobius or Talpa. The most distinct indication of this is in the absence of the lens in the adult animal.

With reference to it Schlampp says ('92, p. 555): "Die Linse [in Proteus] wird gleichzeitig mit der Einstülpung der primären Augenblase angelegt, wächst in den sekundären Augenbecher hinein, wo sie bei der Larve noch in der Gegend des vorderen Augenpoles zu finden ist. Sie kommt aber über die zellige Struktur der embryonalen Linse nicht hinaus, erleidet vielmehr durch Nichtgebrauch alsbald eine Rückbildung, so dass sie bei ganz jungen Thieren an Grösse und Zellmasse schon bedeutend reducirt ist, im späteren Leben aber resorbirt wird und spurlos verschwindet."

The lens is present in Talpa, though it retains its embryonic cellular structure throughout life, wholly according to Hess ('89, p. 8), partly at least according to Kohl ('89, p. 385) and others. In this regard, then, it is more rudimentary than the lens of Typhlogobius. The choroid is present in Proteus, consisting, according to Kohl ('89, p. 406) "aus mehreren Zellenlagen mit reichlichem Pigment, das sich stets in zwei Lagen anordnet, von denen bald die eine, bald die andere die grössere Stärke besitzt. Die innere derselben repräsentirt das vielfach (so auch Hess) schon zur Retina gerechnete Pigmentepithel." It also contains blood capillaries according to both Kohl and Hess. As regards the choroid and the pigment lamella of the retina, it would seem, according to these statements, that the eye of Typhlogobius, with its exceedingly rudimentary choroid and greatly thickened pigment lamella, is somewhat more rudimentary — it may be even degenerate — than that of Proteus; though it must be borne in mind that the choroid is comparatively feebly developed in normal teleostean eyes.

In Talpa the choroid reaches a relatively slight development, and has little pigment, while the pigment layer of the retina is highly developed (Hess, '89, pp. 3 and 4). In this regard it more nearly agrees with Typhlogobius than does Proteus. The iris, considerably thickened with pigment, the ligamentum pectinatum, ciliary body, and ciliary muscle, are all present, though reduced, in Talpa, according to Hess.

With regard to the retina of Proteus, Schlampp's statement in his summary is as follows: "Die Retina breitet sich, Mangels des central Glaskörperraumes, nicht flächenhaft aus, sondern wird eine solide Kugel, welche axial von Sehnerven durchzogen wird. In ihrem histologischen Baue weicht sie nicht wesentlich von der Netzhaut der Amphibien ab, die Endapparate erreichen aber die endgültige Form nicht."

Also according to Kohl ('89, p. 407), the nerve-fibre layer, the ganglion-cell layer, the inner and outer nuclear layers, and the inner reticular layer are present. Regarding the outer reticular layer and the optic cells he says: "Zwischen den beiden Körnerschichten habe ich die äussere reticuläre Schicht (Zwischenkörnerschicht) immer durch eine fortlaufende, oft gar nicht so schmale Spalte repräsentirt gefunden. . . . Die Sehzellen, die sich mit Picrocarmin meist sehr schön färben lassen, zeigen ungemein mannigfache Formen: bald ganz flach, bald nahezu kreisrund. Oefter fand ich vollkommen entwickelte Zäpfchen, niemals jedoch auch nur annährend stäbchenartige Gebilde. Die Hemmung in der Entwicklung ist eben auch hier schon so früh eingetreten, dass eine ausgesprochene Stäbchen- und Zapfenschicht nicht mehr zur Ausbildung kommen konnte."

Of the retina in Talpa, Hess says that the nerve-fibre layer is very thick near the entrance of the optic nerve, and that the inner reticular layer contains cells; he quotes Leydig and Kadyi to the effect that the optic cells consist exclusively of rods, and he adds ('89, p. 5), "Ueber die anderen Retinaschichten ist Besonderes nicht hervorzuheben." Kohl ('89, p. 384), however, states that "Zäpfchen sind stets vorhanden: oft vereinzelt, oft sehr zahlreich und die Stäbchen nahezu verdrängend. Bei einem Exemplar zeigen die Sehzellen noch jene Form, die sich bei Embryonen eines gewissen Alters findet, und noch nicht erkennen lässt, ob die betreffenden Zellen sich zu Stäbchen oder zu Zäpchen weiter entwickeln werden." It thus appears that the three retinas have reached about the same stage in development; that of Proteus being probably on the whole the most rudimentary, and that of Typhlogobius, at any rate as represented by the one shown in Figure 21, the least so.

As regards the vitreous body, Schlampp finds that it is entirely absent in the eye of Proteus; while Kohl ('89, pp. 406 and 407) finds a structure which he regards as the hyaloid membrane, or "the membrana limitans interna, the only representative of the vitreous body in the Proteus eye." Hess and Kohl both describe the vitreous body as present in Talpa, and, according to the latter, it contains numerous blood-vessels. It will be remembered that no trace of this structure has been found in the eye of Typhlogobius, with possibly a single exception.

All are agreed at present, it appears, that the optic nerve is present in both Proteus and Talpa, though Hess quotes Semper as stating that it is entirely degenerated in Talpa. I find no account, however, of its ever having in either of these animals a pigment sheath in its passage through

the retina, such as occurs in Typhlogobius. But it is interesting to notice in this connection Kohl's description of this portion of the nerve in Proteus. He ('89, p. 408) writes: "Beim Durchgang des Opticus zeigen die Zellen der Retina ein eigenthümliches Verhalten. Ihre Kerne werden sehr langgestreckt und sie ordnen sich um den Nerv in 1-2 dichten Lagen dergestalt an, dass sie schon kurz vor dem Eintritt des Opticus in die äussere Körnerschicht und auf der ganzen Strecke, die derselbe sich durch die Körnerschichten hinzieht, eine Art fester Röhre um ihre bilden." It is quite possible that the pigment sheath described in the Typhlogobius eye may have been preceded by such a cellular sheath as this; but if so, my conjecture that it is derived from the nerve itself, and not from the surrounding retina, would be, of course, erroneous. It is also worth mentioning that Berger ('81, p. 262) has described pigmented fibres arising from the choroid as passing through the optic nerve in some fishes.

We have not yet sufficient knowledge of the minute structure of the eye of any of the other blind vertebrates, Myxine and its allies excepted, to make possible further detailed comparison. With reference to the eyes of the Myxinidæ, it should be said that, from the investigations of J. Müller ('35–41), and, later, W. Müller ('74, pp. 7–15), we know that they are far more rudimentary than in any other vertebrate whatever, unless we admit the exceedingly problematical pigment spot at the anterior end of the nerve cord of Amphioxus to be homologous with the eye. It is, however, instructive to notice wherein the eyes that we have been considering may be regarded as passing along the same degenerative road over which the Myxinoid eye has passed, and in what respects they might seem to be on different roads. The eye of Myxine is buried in the tissue of the head in much the same way as in the other forms, excepting that, in addition to the layers of skin and the connective tissue by which it is covered, there is also a layer of muscle over it, and it is immediately surrounded by a sort of capsule containing in its substance much fat. As the foregoing pages have shown, there is no indication of either the muscle layer over the eye or the fatty layer around it in Typhlogobius, Proteus, or Talpa; but it is of course entirely beyond our power to say that there never could be such structures.

Neither lens nor eye muscles, nor anything that can properly be regarded as a cornea, sclerotic, or iris, are present in the eye of Myxine. The primitive optic vesicle never becomes wholly obliterated, and the retina reaches only a very rudimentary degree of differentiation. W. Müller ('74, p. 14, and Fig. 3, Taf. XI.) recognizes in it, however, the

internal limiting membrane; the inner reticular layer (called by him the neurospongium), and scattered in this the ganglion cells; the inner nuclear layer (called by him the ganglion retinæ); the rudiments of the rods and cones; and the radial fibres. Krause's remarks on the eye of Myxine are interesting. He ('86, p. 19) says: "Sein Auge würde zu den *perotischen* rückgebildeten, wie das von Proteus anguineus zu rechnen sein, und man kann die rudimentär entwickelte Retina deshalb nicht zur Construction phylogenetisches Aufbauten benutzen." It appears to me that the most interesting fact concerning the Myxinoid eye, at least from a comparative point of view, is the entire absence of pigment in it. I may here say that I have made some sections of the eye of a member of this family found at Monterey, Cal., and named by Lockington ('78, p. 793) Bdellostoma stoutii, and can confirm the statements made on this point by all other observers. I have so far found no trace of pigment in the eye. The proximal layer of the primitive optic vesicle remains distinctly cellular throughout life, as always stated, but no pigment appears either in it or in the mesodermal tissue immediately surrounding the eye. If, as seems certain with the rudimentary eyes of the three forms that we have been considering, an increase of pigment is an incident to the gradual diminution in functional importance and structural completeness, I can see no very satisfactory explanation for the absence of pigment in the Myxinoid eye, if we are to suppose, as I take it for granted we must, that it too is the result of arrested development.

Wyman ('54, p. 395; '54[a], p. 18; see also Putnam, '72, pp. 18, 19) has made us acquainted with the eye of Amblyopsis spelæus as far as he was able to with the methods of morphological investigation of his time. And it is altogether probable that all he has made known concerning this species holds good for Typhlichthys subterraneus, since the two forms are so nearly alike that systematists are not fully agreed that they should be considered as separate species.

According to Wyman, the eye of Amblyopsis has "a sclerotic coat, a choroid coat, a layer resembling the retina, a lens, and a nerve." His notes, published by Professor Putnam, give somewhat more of detail as to the structure of these several parts. He says: "Under the microscope, with a power of about twenty diameters, the following parts are satisfactorily made out: . . . 2d, a layer of pigment cells for the most part of a hexagonal form, and which were most abundant about the anterior part of the eye; 3d, beneath the pigment a single layer of colorless cells, larger than a pigment cell, and each cell having a

distinct nucleus; 4th, just in front of the globe a lenticular-shaped, transparent body, which consisted of an external membrane containing numerous cells with nuclei." The pigment layer he regards as representing the choroid, and the layer of colorless cells within — and it should be particularly noticed that it is according to both his description and figures a *single* layer — as representing the retina. It is very desirable, indeed, that these eyes should be studied anew with modern methods of preservation and by means of sections; for, if Wyman's account of the structure proves to be correct, we have here a most interesting deviation from the three forms best known and already compared. It may be supposed that his statement concerning the cellular condition of the lens is correct; for this involves merely the observation that a given structure is composed of cells, while his statement concerning the retina involves an observation as to how the cells in a given cellular structure are disposed, — two quite different matters, as every histologist knows. In this particular the lens of Amblyopsis corresponds, then, to that of Talpa; but in the latter animal the retina is fairly well differentiated, and even in Proteus, where the lens is wholly wanting in the adult, the retina is differentiated to a considerable extent. If Wyman is correct in supposing that the retina in Amblyopsis is represented by a single layer of cells, then we have a condition corresponding more nearly to that found in Myxine than in any other known vertebrate, although even here the retina proper is far from being a single cell layer, but the eye of this latter form has no trace of a lens.

Cope ('64, p. 232) remarks with regard to the blind Silurid, Gronias nigrilabris, that in no case has he found anything representing the lens. Whether a considerable number of specimens were examined with reference to this point, the author does not state; but from the general character of the fish and its eyes, as described, it appears to me quite probable that, as Packard suggests, further examination will lead to the discovery that the lens is not entirely absent.

I cannot refrain from saying at this point a few words on the question which, in reality, induced me to undertake the study of the eye of Typhlogobius, viz. the question of the actual degeneration of functionless organs. There is a belief prevalent among zoölogists, though to just what extent I am unable to say, that, if a structure undergoes degeneration in ontogeny it does so in the reverse order of its phylogeny. It would appear that a degenerating vertebrate eye with its great complexity of organization, this complexity having been taken on by degrees

through a long course of evolution, would furnish an excellent test of this belief. The eye here studied throws very little light on the question, however, — scarcely as much as does that of other known functionless eyes. But when we consider together the facts presented by the eyes of Myxine, Typhlogobius, Proteus, and Talpa, and possibly also Amblyopsis and Gronias, this much seems quite certain: that the lens disappears before the retina; and that, where degeneration takes place at all in ontogeny, the lens is affected first and most profoundly, as seen in Proteus, and probably also exceptionally in Typhlogobius. Supposing the somewhat doubtful instance of a degenerating retina presented by the eye shown in Figure 19 to be genuine, we still have reason to believe that its degeneration has been preceded by that of the lens, since the latter body is undoubtedly absent in this specimen. There can scarcely be a doubt, from physiological reasons, that the retina is considerably older, phylogenetically, than the lens, even though it can hardly be said to be so ontogenetically.

The Integumentary Sense Organs.

At present I treat this subject no further than pertains to the question whether the loss of sight in Typhlogobius has been compensated by an unusual development of the sense of touch, leaving the consideration of any morphological significance that the sense papillæ may have with the hope that they may be studied developmentally at some future time.

From the testimony of numerous writers, there is no doubt that compensations for such loss by the super-development of the other special senses, hearing, smell, and touch, are common among animals both invertebrate and vertebrate. For a discussion of this subject see Packard ('86, pp. 123–130).

My conclusion with reference to the tactile sense in Typhlogobius is, that in all probability it not only has not increased, but has actually diminished *pari passu* with the diminution of the power of sight. The reasons for this conclusion are that several — at least four — genera of the Gobiidæ closely related to Typhlogobius are as well provided with tactile papillæ as is the blind fish, these organs being considerably more numerous and more widely distributed on different parts of the body in the other fishes than in Typhlogobius. The genera to which I refer are Gobius, Gobiodon, Lepidogobius, and Clevelandia. The last two I have examined myself. The arrangement and

distribution of the papillæ of Typhlogobius are shown, except for a few scattering ones to be spoken of shortly, in Plate I. Figure 3, *pap.*

There are two series near the edge of each side of the lower jaw, running parallel with it. The series of one side do not quite unite, anteriorly, with those of the opposite side, the interval between their ends being occupied by a slight prominence in the epidermis. Posteriorly the series extend beyond the angle of the mouth and turn upward somewhat to terminate about on a level with the mouth opening; the rows nearer the median line, however, extending slightly farther than the ones nearer the edges of the jaws (Fig. 3). The papillæ of the inner series are considerably larger than those of the outer series, there being about six of the former to thirteen of the latter. The larger ones are on the average about 0.08 mm. in diameter, though the size varies considerably. The papillæ of the outer series are situated on a quite prominent ridge, while the inner ones are, on the contrary, in a shallow furrow. These ridges and furrows are, however, apparently a part of the longitudinal foldings in the integument that are characteristic of this region of the head, rather than structures expressly for the accommodation of the sense buds. Another series of papillæ is found on each side of the head above the mouth, and having very nearly the same direction as those below, though inclining toward the latter somewhat in their course backward. These extend anteriorly to near the tips of the fleshy knobs shown at †, Figure 1. The papillæ above the mouth are of about the same size as the smaller ones on the lower jaw. Still another series is found on each side of the head on the operculum, extending however at a right angle, or nearly so, to the series already described (Fig. 3). These are also of the smaller variety. The number in both this and the upper-jaw series is more variable that in the lower-jaw series, though the transverse series never extend far on to the top of the head.

In Lepidogobius and Clevelandia both lower-jaw series are present, and have precisely the same arrangement and form as in Typhlogobius; and in addition papillæ are numerously present on various parts of the head and body where they do not occur in Typhlogobius. Thus on the head of Lepidogobius there are at least several hundred in addition to the ones on the lower jaw. On each side of the head, beginning at a point a little above the mouth and somewhat nearer its angle than the end of the snout, four rows take their origin and diverge irregularly. The row nearest the mouth bends downward somewhat as, in its backward course, it reaches the angle of the mouth, and it extends,

as do all the rows, considerably farther back of the angle of the mouth than it does in front of that point. The uppermost row of the four runs upward to near the posterior and lower quadrant of the eye, where it takes a trend more directly backward, and extends for a considerable distance back along the dorsal limit of the operculum. The other two rows are situated considerably nearer the lower than the upper row, and are nearer each other than either is to the uppermost or the lowermost row. They also run very nearly parallel with each other. The lower one of these two middle rows contains the fewest and largest papillæ of the head, those of the inner mandibular series excepted. There are about twenty-five papillæ in the lower row, nineteen in the next, thirty-five in the third, and fourteen in the fourth.

Head of Lepidogobius, showing the distribution of the tactile Papillæ. × 1½.

Many of the papillæ of this species are distinctly excavated on their summits, and in such a way as to show such an arrangement as is described by Solger ('80, p. 375) to exist in the lower jaw of Gobius minutus. The excavations are in the form of grooves, or creases, which extend entirely across the summit of each papilla, each groove being somewhat broader in its middle than at the ends. In some of the rows these grooves are directed lengthwise of the row, while in others they have a direction crosswise of it. There is some variation in the direction of the grooves in the papillæ of the same row, and considerably more in some rows than in others; but the constancy in some of them is noticeable. In the larger papillæ the grooves are much more pronounced than in the smaller ones, in many of these latter the excavation being a pit rather than a groove. In the lower-jaw series of this species, the grooves of the inner rows extend crosswise to the axis of the head, and those of the outer row lengthwise, thus corresponding to the condition found by Solger in Gobius minutus.

In addition to the four series thus described, there are numbers of papillæ scattered on other portions of the head, particularly about the tip of the snout and on the opercular apparatus; in these regions they are particularly numerous on the suboperculum. Also on each side of the body, beginning immediately behind the pectoral fins, there are about thirteen transverse series, containing from five to ten papillæ

each; and still lower down are from five to seven additional transverse series, extending well down on the ventral surface of the body. It is possible that these lateral series are derived from a segmentally arranged type; but if to they have certainly deviated greatly from the typical arrangement, as they also vary both in the number of series and in the number of papillæ in each series. The papillæ here are considerably smaller, on the whole, than those of the head. There are, finally, a number of papillæ scattered around the bases of the fins, both pectoral and pelvic.

In Clevelandia there are about twenty-five transverse series on the sides of the body very uniformly segmentally arranged, being situated on the inter-myotomic septa. The series contain an average of about five papillæ each, though the number varies considerably. I have worked out the precise arrangement of the series on the septa, — for not quite all the septa have papillæ, — and of the number of papillæ to each series in a considerable number of specimens, as it has appeared to me that this may have considerable morphological significance. It is not necessary for my present purpose, however, to give the results in detail. It is worthy of mention that the transverse series on the body of Clevelandia are situated in shallow ditches, the anterior wall of these being deeper and more abrupt than the posterior. In no case have I been able to find the papillæ situated in canals, or in grooves that approach canals, as is so common in fishes, and is said to be the case in Gobius niger, by Merkel ('80, p. 28). All writers agree, however, that in the genus Gobius by far the greater portion of the papillæ are free on the surface of the body (F. E. Schultze, '76; Merkel, '80; Solger, '80). We know from the last two of these authors that both the genera Gobius and Gobiodon have free transverse series of papillæ on the sides of the body. With reference to this subject, Solger ('80, p. 378) says: "Bei Gobius konnte ich 'Querreihen von 3–7 Organen' constatiren; auf Beziehung der Organreihen zur Metamerie des Leibes achtete ich damals leider noch nicht. Auch Gobiodon hat am Rumpfe freie Seitenorgane, die in Querreihen auf Coriumpapillen stehen und höchst wahrscheinlich durchweg segmental angeordnet sind." And Merkel ('80) shows three of these series in his Figure 4, Taf. IV.

It being, then, evident that so many of the near relatives of Typhlogobius are provided with sense papillæ on the sides of the body, the question at once arises whether any are found in the corresponding region on the blind fish. Very naturally it was to the smallest specimens in my possession that I turned to begin the search for them. On

each of the two individuals 19 mm. long, papillæ were found on the sides of the body, and on one of them a few on the head, besides in the regions where they occur regularly In one of these the papillæ on the right side of the body were distributed in what I regard as representatives of nine of the transverse series described in Clevelandia. The first and second series behind the pectorals were represented by one papilla each; the third and fourth, by three papillæ each; the fifth, sixth, and seventh, by two each; and the eighth and ninth, by one each. The series were evidently segmentally arranged, though not all were on consecutive segments; thus between the third and fourth series were two myotomic plates; between the fourth and fifth, four plates; between the fifth and sixth, two plates; between the sixth and seventh, one plate; and between the eighth and ninth, two plates.

Figure 25, Plate IV., shows the arrangement of a group of papillæ on the right side of the head of this same individual. As seen by the figure, seven of these papillæ were much larger than the remaining ones, and were situated on quite prominent ridges of the skin.

Although the papillæ have been diligently searched for on the sides of the body of other specimens, they have been found on the two small ones only. The question at once arises, Are the papillæ absent from the larger ones because they have degenerated and completely disappeared during the life of the individual? All the evidence I have on this point is contained in the facts presented. That the papillæ have been found only on the two small specimens examined, and that they have not been found on any of the numerous large ones, certainly suggests very strongly an affirmative answer to the question. It must be said, however, that a considerable percentage of my larger specimens are not so well preserved but that the papillæ may possibly have been present in them and escaped detection. But some of them are well preserved, and were the papillæ present they would, I am sure, have been found.

That the sense papillæ are less numerous on Typhlogobius than on several, at least, of its near allies, is evident. The question may now be asked, Is it not possible that, although there has been no compensation for the loss of sight by an increase in number of the tactile papillæ, such a compensation has been brought about by a higher development of the individual papillæ themselves? So far as structural evidence is concerned, this is certainly far from probable. Figures 23 and 24 (Plate IV.) show sections of two papillæ of the inner mandibular series of Typhlogobius; and for the purpose of comparison a section of a

papilla from the same region in Lepidogobius is given in Figure 26. Between Figures 24 and 26 there is considerably less difference than may often be seen between sections of different papillæ of the same animal. Thus the sense cells proper (*cl. sns.*), which are very regular in their arrangement in Figure 26, are quite irregular in Figure 24; but Figure 23 agrees much more closely in this particular with Figure 26 than with Figure 24. Indeed, the difference is due to the position and direction of the section, both arrangements being found on sections of one and the same papilla at times. The cuticular spikes, so distinctly seen on the sense cells in Figure 23, are much less distinct in any of the Lepidogobius sections examined; but they are only exceptionally seen with such clearness in sections of the blind fish papillæ. It will be noticed that a considerable space (*tt.*) exists in Figure 26 between the sensory cells and the underlying nuclei of the supporting cells, in which there are no nuclei; and that such a space does not appear, at least conspicuously, in either of the figures from Typhlogobius. This, however, is not a difference of material significance, since in many sections of the papillæ of the blind fish such spaces do exist. In Figure 24, it will be observed that a blood-vessel, *va. sng.* (the leader from which has been misplaced in the engraving), penetrates far into the interior of the papilla. A similar vessel is present in Figure 26, though it does not extend quite so far into the base of the papilla, nor have I in any case found it to do so in this species, though it is true I have not examined as large a number of sections of Lepidogobius as of the blind fish; but the difference, if distinctive of the two forms, is nevertheless insignificant. Neither as regards the mantle cells (*cl. mt.*), nor the relation of the papilla to the epidermis, — i. e. its extending entirely through the thickness of it, — nor the way in which the nerve approaches and enters the papilla, nor the character of the immediately underlying subepidermal tissue, is there the slightest characteristic difference to be made out between the two species in such papillæ as are represented in Figures 24 and 26.

In only one point a difference may possibly exist between them, though I have not yet been able fully to satisfy myself of this. By Figure 23 it will be seen that the papilla is wholly and deeply buried in the epidermis, only a small pore (*po.*) communicating with the outer world. The apparent bridge across the pore near the papilla is probably a point of contact merely, as adjacent sections show. The whole appearance is as though the papilla had been withdrawn into the epidermis; for not only is the latter much thickened immediately around

the papilla, but the inverted hopper-shaped outline which the inner surface of the epidermis shows immediately under the papilla in most cases where the latter reaches out freely to the surface (as in Figures 24 and 26), is here entirely obliterated. Another fact that seems to favor the view that the papilla has been withdrawn, is the very distinct flask-shaped excavation in the summit of the papilla itself, seen in Figure 23 (*fos.*), while in the sections represented in the other two figures no such excavations are present. A natural explanation for this would seem to be that, on being drawn in, the middle portion of the papilla with the sense cells had been more depressed than the mantel cells. This may be the true explanation, but in one instance I have found the excavation in the papilla, even though the papilla itself protrudes through the epidermis, even more distinctly than in Figures 24 and 26; yet it should be mentioned that in this exceptional instance the papilla is considerably narrower in proportion to its length than those shown in the figures just referred to, or than they usually are. I have searched in vain for muscle fibres that could bring about such a withdrawal, and have no other evidence than that presented that it takes place; nor have I often found the papillæ thus buried, and never in Lepidogobius. Leydig ('79, p. 25) has suggested the probability of the contractility of the cellular elements of the papillæ as the cause of an apparently similar condition in Acerina cernua.

A word should perhaps be spoken at this point on the possibility of the loss of sight being compensated by a higher development of the organs of hearing or smell. This subject lies outside of the purpose of the present paper, and I have given only superficial attention to it. The ears examined in dissected specimens mounted in glycerine do not appear unusually large. The minute structure I have not examined; but from this morphological evidence, taken with the fact that all my efforts to get from my single living specimen responses to sounds of various kinds were unavailing, I am inclined to believe that the sense of hearing is not largely developed.

My sections of the snout show the olfactory epithelium to be very well developed, though apparently not more so than in other bony fishes, and certainly not so highly as in some of the long-tailed amphibia that I have examined.

What we know about the compensatory development of the tactile organs in other vertebrates with rudimentary eyes may be summed up as follows. It is well known from the writings of Tellkampf, Wyman, Leydig, Putnam, Wright, and others, that the tactile papillæ are well

developed on the head and sides of the body of both Amblyopsis and Typhlichthys. According to Packard ('86, p. 127), Tellkampf regarded these papillæ "as without doubt increasing the tactile sense." I have not seen this paper of Tellkampf's, and do not know whether his meaning would be that the tactile sense is increased as compared with what it was in the same species before it was deprived of sight, or merely that it is great as compared with other bony fishes. Leydig also believes that the tactile organs perform such a compensatory office ('83; see also Wright, '84, p. 272). Packard ('86, pp. 127, 128) gives extracts from several letters of Dr. John Sloan that are interesting in this connection. Although the writer does not expressly state his belief that the sense of touch has been highly developed for the purpose of compensating the lack of sight, he still gives very convincing evidence of its extreme acuteness from personal observation on the fishes in their native surroundings. It should also be noticed that he specially tested their powers of hearing and the effect of light upon them, and to both he says they "manifested total indifference." Sloan's observations were on Amblyopsis. Wyman ('72, p. 19) has described the ear of this species as being "largely developed" in all its parts, and Cope ('72, p. 410) found the sense of hearing "evidently very acute." As to the question whether the sense papillæ in Amblyopsis and Typhlichthys are in reality developed as a compensation for the loss of sight, the testimony furnished by Chologaster is of the greatest importance. Although this genus was discovered and named by L. Agassiz in 1843, its characters were best made known by Putnam. He ('72, pp. 22, 23) says: "In the genus Chologaster we have all the family characters as well expressed as in the blind species, though it differs from Amblyopsis and Typhlichthys by the presence of eyes, and the absence of papillary ridges on the head and body, and by the longer intestine and double the number of pyloric appendages, as well as by the position of the ovary."

In 1881, S. A. Forbes ('82, p. 3) discovered a fish in Southern Illinois which he identified as belonging to the genus Chologaster, but representing a new species. With reference to the point that we are now considering, the author writes: "The most important and interesting peculiarity of this species indicates a more advanced stage of adaptation to a subterranean life than that of its congeners. On all the surfaces of the head appear short rows of peculiar tubercles. . . . When thus exposed [by being freed from the adjacent epidermis], they closely resemble the papillæ of Amblyopsis in form and size, and are similarly cupped at the tip." Again (p. 5) he says: "The extraor-

dinary development, in only a part of the genus, of a special sensory apparatus peculiarly useful to a fish unable, for any cause, to see, points the same way, [i. e. to the supposition that this genus has a shorter subterranean history than Amblyopsis,] and gives evidence of a *progressing* adaptation of these fishes to their unusual abode. The intermediate relation of the sensory tubercles of Chologaster to the much smaller ones of young fishes and the permanent papillæ of Amblyopsis, points out the evident origin of the last through the permanency and higher evolution of structures evanescent in the young." This is probably the clearest case furnished by vertebrates of the loss of sight being recompensed by a higher development of the tactile sense.

As regards the tactile papillæ in the Cuban blind fish (Lucifuga), Putnam ('72, p. 9), who examined a specimen sent to the Museum of Comparative Zoölogy by the discoverer of the fish, Professor Poey, says: "In the Cuban blind fish we find ciliary appendages on the head and body quite distinctly developed, evidently of the same character as those of Amblyopsis, and answering the purpose of tactile organs. . . . There are eight of these on the top of the head, . . . and quite a number arranged in three rows on each side of the body, showing that the tactile sense is well developed in these fish."

This, so far as I am aware, is all that is known on the subject, and can be regarded as furnishing nothing more than a probability that touch papillæ have been here developed to compensate the fish for sightless eyes. The writer just quoted remarks further, that it is singular that the barbels on the jaws, so commonly found in the Cod family and its allies (to the latter of which the Cuban fish belongs), are entirely wanting. As is well known, Lucifuga is a cave dweller, and consequently the conditions which have produced its rudimentary eyes are more similar to those that have produced the corresponding change in Amblyopsis than to those that have had the same effect on Typhlogobius. And this fact may strengthen the probability above referred to; for, from the difference in conditions of life, Amblyopsis and Lucifuga are in all probability much more active than Typhlogobius, and this would make the tactile sense more useful to the first two species than to the last one.

We will now notice the condition of the blind deep-sea fishes with reference to the touch papillæ. The three forms described by Günther ('80), Typhlonus nasus, Aphyonus gelatinosus (p. 548), and Ipnops murrayi (p. 585), are all without barbels, and, so far as known, other special tactile structures. The two genera first named

belong to the same family as Lucifuga, and consequently the remarks made concerning the absence of barbels in the latter will apply in a measure to these genera, and with reference to Lucifuga receives more force by the statement of Günther that they "are Brotula organized for a subterranean life" (p. 547); and in the genus Brotula, which has eyes, the snout is provided with barbels.

Through the kindness of Mr. C. H. Townsend, naturalist of the United States Fish Commission Steamer "Albatross," I have been able to examine, though somewhat superficially, a specimen of Ipnops, — probably the same species as the one above mentioned, — and, so far as I could discover, Günther's statement that it is "deprived of organs of sight and touch" ('87, p. 190) is strictly correct. The same author makes the following as a general statement on this subject: "Special organs of touch are not more generally developed in deep-sea fishes than in the littoral fauna. . . . As such may be considered . . . the more or less detached rays of the pectoral fin of . . ., and especially of Bathypterois, which possesses but rudimentary eyes." ('87, p. xxxi.) And in another connection the same author (p. 722) says: "Beyond that depth [two hundred fathoms] small-eyed as well as large-eyed fishes occur; the former having the want of vision compensated by tentacular organs of touch, whilst the latter have no such accessory organs."

I have not been able to find any direct statements concerning tactile papillæ on the several species of blind Silurids of South America mentioned by Günther (Packard, '86, p. 107), nor have we any knowledge that such structures are found on Gronias, the blind representative of the same family from Pennsylvania.

The Integument.

I was led to a study of the integument by the question having arisen as to why the quantity of pigment should have *diminished* in it, while under the same conditions of life it had *increased* in the eyes. That such diminution had taken place in the skin was inferred from the generally much lighter appearance of the largest preserved specimens as compared with the smallest. In the latter, the whole dorsal portion of the body and head is covered with a great number of distinct pigment cells (Fig. 1), while the large specimens never present anything like so conspicuous a pigmentation; and in the majority of cases they appear, on cursory observation, to be almost white.

Closer examination shows, however, that the pigment is in reality

present in large specimens as well as in small ones, in quantity almost, if not quite, as great in the one case as in the other; but that it becomes disguised in the former case, and in a manner that will appear presently.

Figures 9 and 10, Plate II., are from sections of the integument and immediately underlying tissues of the dorsum of the head of two individuals, 19 mm. and 72 mm. long respectively. It will be noticed that the epidermis does not differ essentially in thickness or structure. In Figure 9 it is about 0.028 mm., while in Figure 10 it is slightly thinner, though in reality it should be a little thicker, some shrinkage having taken place here. With the sub-epidermal connective tissue (*con't. tis.*), however, the case is quite different. In Figure 9 its thickness is 0.056 mm., while in Figure 10 it is about 0.025 mm., over the pigment; and it will be seen that in both the pigment (*pig.*) is situated in the deepest stratum of the connective tissue, adjacent, or very nearly so, to the muscles (*mu.*).

Within the sub-epidermal layer, in all the larger specimens, there is found a dense and intricate network of blood-vessels and capillaries. In general, the vessels of this network appear to run quite uniformly in one plane, situated about midway between the epidermis and the pigment layer. In many places, however, they will be seen, in sections, to approach very close to the epidermis, or at least to its basement membrane, which is at times quite distinct. These vessels are shown in Figure 10 (*ra. sng.*); also in Figures 4 and 11 as surface views from nitric acid glycerine preparations. Their walls are so thin as to be scarcely distinguishable from the surrounding connective tissue. Indeed, in parts of many sections their presence can be detected only by the blood-corpuscles, which are very different in appearance from the connective-tissue cells, owing to their larger size, more elliptical outline, distincter nuclei, and slightly yellowish homogeneous non-stainable (in hæmatoxyline at least) cell protoplasm. The connective-tissue layer in which these vessels are situated is somewhat different from either the layer above or that below it: its fibres are more closely compacted together, it contains more cellular elements, and it takes stain rather more readily than do the adjacent layers. I am inclined to believe that many of these cellular elements are leucocytes. I may here add that the blood-vessels shown in Figures 4 and 11 are none of them of capillary fineness, since in none of them are the blood corpuscles arranged in a single row, as is characteristic in capillaries. The capillaries are still smaller, and from the method of preparation and delineation are not shown here.

It is unquestionably to the presence of this highly developed vascular network that the pink color of the living fishes is due; and it is undoubtedly by this, in part, but mostly by the much thickened sub-epithelial connective tissue, that the pigment is disguised in the preserved specimens.[1]

And now as to the reason for this highly vascular condition of the skin, which is certainly unusual, as I have convinced myself by examining the integument of several other bony fishes, both by sections and by the same methods of treatment that were used in preparing the specimens shown in Figures 4 and 11.

I will consider the several explanations that have suggested themselves, in the order in which they have occurred to me.

When I first saw the living specimens, I supposed their pink color to be due to the fact that the pigment had disappeared from the skin on account of the constant darkness in which the fishes live; and that, it having thus become somewhat translucent, no scales whatever being present, whatever of vascularity there might be in the tissues of the body wall became visible through the integument. This explanation lost all its force, of course, as soon as it was noticed that the pigment is present in large as well as in small specimens, and that the blood-vessels are situated *between* the pigment layer and the epidermis, and not *under* the former. I would not be understood to mean by this that the pigment layer is so dense that it would much obscure the vascular-layer were it superficial to the latter.

The next hypothesis that presented itself to me was suggested by the fact mentioned by Dr. Eigenmann, that the crustacean with which the fishes so constantly live is also of the same pink color. Have we here a case of protective resemblance? An entirely satisfactory answer to this question cannot be given until we know more of the habits of the fish in its native conditions of life, and also of the structure and habits of the crustacean in company with which it lives. So far, however, as our present knowledge enables us to see, there are some quite serious obstacles in the way of this supposition. It is probable that the fish

[1] I may add, that on examining several large specimens preserved in alcohol exclusively, I find that the pigment is very distinctly seen on the whole dorsal surface, without removing the skin. As the epidermis in these specimens is quite loose as compared with that of specimens preserved in picro-nitric, picro-sulphuric, or Perenyi's fluid, I explain the greater distinctness of the pigment by supposing that in the alcoholic specimens the sub-epithelial connective tissue has shrunken more by dehydration than it has in the other methods of fixation, and also more than has the epidermis.

has adopted its present mode of life as a means of escape from its enemies, so that protective coloration could be of no use, and consequently natural selection would have no power to establish the color.

It is true that there are recorded a few cases of animals that are apparently protectively colored, which at the same time depend upon concealment to escape their enemies; e. g. the caterpillar of the moth Mania typica (A. R. Wallace, '89). But these are certainly very exceptional; and if the law of natural selection is to be held as applying to them at all, we are compelled to assume that either the coloration must have been produced in some other way than through it, or that neither the color protection nor the concealment is adequate in itself to effect the degree of protection necessary for the preservation of the species. On this supposition, it is possible that natural selection has been operative in producing the color; but Dr. Eigenmann ('90, p. 68) tells us that Typhlogobius "never leaves its subterranean abode"; and the extent to which the eyes are reduced affords very strong proof in confirmation of this statement. Again, on physiological grounds, it would seem that had the color been produced for the mere purpose of the color alone, it would have been effected by a deposition of pigment, and not by such an enormous increase in the quantity of blood-vessels and blood; for certainly the former would have been more economical.

And this brings me to what I believe to be the true explanation of the condition. I believe it to be for the purpose of cutaneous respiration. Says Prof. N. Zuntz ('82, p. 114): "Wo auch immer das Blut mit der Atmosphäre oder mit gashaltigem Wasser in Contact kommt, muss, in derselben Weise wie in der Lunge, ein auf Ausgleich etwaiger Spannungsänderungen hinzielender Diffusionsstrom der Gase auftreten." The conditions for such a diffusion seem to be present here. That cutaneous respiration takes place as a normal process in many vertebrates, both terrestrial and aquatic, is generally admitted by physiologists.[1] For the present purpose I need only to consider in some detail what is known about the process in some of the aquatic forms.

Spallanzani (1803, pp. 71, 114) was the first to show that the frog by means of respiration through the skin continues to live for a long time in air after the extirpation of the lungs. W. F. Edwards ('24, pp. 41-62) confirmed Spallanzani's results, and added the observation that this

[1] For a discussion of this question, see the larger works on physiology, and particularly Milne-Edwards, '57, pp. 632-635, and Hermann, '82, pp. 114-117.

animal would continue to live in water as well as in air, particularly in flowing water at a low temperature.

Berg ('68) investigated the same subject, and, while confirming the results of his predecessors so far as the fact of cutaneous respiration is concerned, concluded that the quantity of carbonic acid gas exhaled is less than that found by Regnault and Reiset. Less attention appears to have been given to the subject of cutaneous respiration in fishes than to the same process in amphibians and mammals; though Spallanzani, and later Humboldt and Provençal ('11, p. 86), found it to occur in these animals to a slight extent.

Quincaud ('73, p. 1143) found that an eel of 530 grams' weight absorbs 0.58 c.c. of oxygen in an hour through the skin.

With this attempted explanation of the color of Typhlogobius the question at once arises, Is this color peculiar to this fish, or is it common to all others that live habitually excluded from the light as this one does? If all the other blind fishes have the same color, and from the same cause, viz. from the vascularity of the integument, then we should have to suppose the same explanation to apply to all; and this would diminish its probability, though of course it would not necessarily wholly invalidate it. In speaking of the color of blind fishes, Professor Putnam ('72, p. 8) gives a list of seven partially or wholly sightless genera of the family Siluridæ, found in various parts of South America, Africa, and Asia. Of their color he says: "All the other members of this family [Siluridæ] having rudimentary or covered eyes are also dark colored; while the blind fish of the Mammoth Cave and of the caves of Cuba are nearly colorless." Concerning the color of Gronias nigrilabris, already mentioned in other connections, Cope ('64, p. 232) says: "The color of the upper surfaces, tail, fins, barbels, and under jaw is black; sides varied with dirty yellow, abdomen and thorax yellowish white." And this author remarks in the same connection that the "dark pigment of the skin of this animal comes off upon the hands in handling it."

Concerning the color of the several species of the three blind, or nearly blind, groups of the Gobiidæ other than Typhlogobius, I gather the following from Günther ('61, pp. 133–138).

In the characterization of the group Amblyopina the eyes are spoken of as "very small, and more or less hidden." No mention is made in this connection of the color, though the name Amblyopus roseus (Cuv. and Val., XII. 164), as applied to the whole genus Amblyopus, is given in a foot-note. Of the eight species enumerated one is said to have "eyes

inconspicuous," color "greenish olive (in spirits)"; the color of another is "greenish," no mention of the eye; another is "rose-colored," no mention of the eye, nor statement as to whether this is the color in life or in spirits; a fourth is "brownish with darker spots, . . . eye small and indistinct"; another, "eyes invisible," no mention of color. Of the remaining three, no mention is made of either the eyes or the color, but for the name in one species *rubicundus* is given as a synonym. Of the genus Trypauchen two species are described, one of which is characterized as "reddish (during life), brownish (in spirits)," the other as "uniform rose-colored." No mention is here made of the condition of the eyes, and I know them to be rudimentary only by the list of blind fishes given by the same author (Packard, '86, p. 107).

In the characterization of the genus Trypauchenichthys the eyes are said to be "very small, scarcely visible," and the only species described is "rose-colored (Bl.)." Nothing is given to indicate that these fishes live particularly excluded from the light. The genus Amblyopus is said to be "confined to the coasts, estuaries, and fresh waters of the East Indies, extending northward to China and Japan; one species from the west coast of South America." The genus Trypauchen is from the "East Indian Seas" and the "fresh waters of Borneo," and Trypauchenichthys is from "rivers of Borneo."

We are not informed whether the several shades of red here mentioned are due to pigmentation; but from the facts that there are several shades, that in some of the species the color seems to persist in the alcoholic specimens, and that the fishes come in a category many of which — particularly of the related genus Eleotris, with eyes normally developed, inhabiting much the same regions — are of similar shades of color, it appears probable that such is the case.

Perhaps the most interest attaches to the color of the Mammoth Cave blind fishes and those of the caves of Cuba; for these are without any question completely deprived of the influence of light. Cope ('72, p. 410) speaks of Amblyopsis spelæus as swimming "in full sight like white aquatic ghosts"; in his original description of Typhlichthys subterraneus, Girard ('59, p. 63) gives its color as a "uniform dull yellowish white tint"; and both these species as well as the Lucifuga are referred to by Putnam as being "nearly colorless," as already mentioned. Also Jordan and Gilbert ('82) describe both Amblyopsis and Typhlichthys as "colorless," and in the same way Günther ('80, p. 618), who regards the two as belonging to the same genus, speaks of the body as colorless.

I have dwelt thus at length on this question of color in other blind fishes because Eigenmann ('90, p. 68) has said with reference to the color of Typhlogobius that "in its pink color and general appearance this fish much resembles the blind fishes inhabiting the caves of Southern Indiana." I suppose this to refer to Amblyopsis, as there is not to my knowledge any other blind fish known from the caves of this region. Whether Eigenmann's statement about the color of the Indiana fishes is to be taken as opposed to those quoted from other writers or not, the most significant fact for our purpose is that there is certainly no such degree of vascularity in the integument of Amblyopsis as is found in Typhlogobius. I have had opportunity to examine a well preserved alcoholic specimen of this species, obtained by Professor Mark from Professor Putnam. I prepared fragments of the skin in the same way that had been employed in studying that of Typhlogobius, and found the blood-vessels here to be even less abundant than in the integument of the Clevelandia and Lepidogobius that I have examined.

The most serious objection, I think, to the supposed respiratory function of the skin lies in the thickness and density of the epidermis, and the fact that the entire surface is thickly beset with the slime-secreting cells (see Figs. 9, 10, and 17). I do not believe, however, that the epidermis here would offer greater resistance to the interchange of gases than would that of the frog; certainly, as regards the integumentary glands and their products, the frog's skin can hardly be more favorably constructed for a respiratory function than that of the blind fish. When we remember the dense cuticular layer that covers the entire surface of such animals as the earth-worm, where all the respiration must be carried on through the body wall, this obstacle does not seem so great. Moreover, in Cobitis fossilis, where intestinal respiration is well known to take place to a considerable extent, although it was long supposed that no epithelium was present in the region of the intestine, — in which from the richness of the blood-vessels the respiration is supposed to be carried on, — Lorent has shown not only that there is an epithelium present, but that it consists of two layers, a superficial layer of flat polyhedral cells, and beneath this a layer of stratified cylindrical epithelial cells, among which are scattered beaker cells (Wiedersheim, '86, p. 572).

Of course the ultimate test of my theory must be made by physiological experimentation, and I hope to be able to do this before long. I cannot suppose gill respiration to be to any great extent supplanted by integumentary respiration, since the gills appear to be normally developed. It is necessary, then, to suppose that the latter method supple-

ments the former; and this may have become necessary from the peculiar mode of life of the animals. It is quite certain that the water of the small holes under stones, in which they live, would contain less aerating oxygen than would that of the open sea; and consequently a greater absorbing surface would be essential in order to effect a normal aeration of the blood.

Summary.

The facts observed and the conclusions reached may be summed up as follows.

The Eyes.

1. In the smallest examples studied the eyes, though very small, are distinctly visible even in preserved specimens, — so distinctly that the lens is plainly seen. In the largest examples, on the other hand, they are so deeply buried in the tissue as to appear even in the living animals as mere black specks, while in preserved ones they are in many cases wholly invisible.

2. Neither in small nor in large specimens does the epidermis over the eye differ in thickness or structure from that of adjacent regions. In the large individuals the much greater thickness of the tissue here is brought about by an increase in the sub-epidermal connective tissue, the growth of which can be seen taking place in the embryonal connective-tissue cells that are found here.

3. As is the case with rudimentary organs generally, the eye is subject to great individual variation in size, form, and degree of differentiation.

4. The only parts of the normal teleostean eye no traces of which have been found are the argentea, the lamina suprachoroidea, the processus falciformis, the cones of the retina, the vitreous body proper, the lens capsule, and in one specimen the lens itself.

5. In the parts present the rudimentary condition of the organ is seen in the very slight development of the choroid, no cellular elements being present in this excepting in the chorio-capillaris, and here to a quite limited extent, the rest of that layer being composed exclusively of pigment; in the fact that the choroid gland is composed entirely of pigment; in the fact that the iris, though of fully the normal thickness, is almost entirely of pigment, there being on its outer surface in some specimens a small amount of cellular material, which probably represents the ligamentum annulare; in the great proportional thickness of the pigment layer of the retina and the entire absence in it of anything except-

ing pigment; in the incomplete differentiation of the layers of the retina, there being in some individuals scarcely more than a trace of the external reticular layer separating the two nuclear layers, and there being in no specimen studied a retina sufficiently developed to enable one to homologize with certainty the layers marked out; in the minute size of the optic nerve, and the fact that it is ensheathed in a thick layer of pigment for nearly its entire course through the retina; and, finally, in the small size of the motores oculi.

6. The surest evidences of actual degeneration are found, first, in the greatly augmented quantity of pigment in all the portions that are at all pigmented in the normal eye; and, secondly, in the presence of pigment in regions where none is found in the normal eye, as in the hyaloid membrane (Plate II. Fig. 12, *pig.''*).

No undoubted instances of degenaration through the breaking down and dissolution of the tissue without the formation of pigment, such as have been described particularly by Looss, have been found, though in a single specimen (the one in which no lens is present) a process of this nature may be taking place.

7. On comparing the eyes of all blind vertebrates that have been most carefully studied, we find that, in the several degrees of incompleteness of development represented by the different species, all may, in a general way, be said to be passing along the same degenerative road. There are apparently, however, a few interesting exceptions to this. The most marked of these exceptions is found in the entire lack of pigment in the eyes of the Myxinidæ, whereas in all other rudimentary eyes an increase of this substance over what exists in normal eyes is found.

8. The eyes of blind vertebrates furnish very little evidence on the question whether structures in undergoing actual degeneration in ontogeny follow the reverse order of their phylogeny. The little that may be regarded as bearing on this point is without much doubt of an affirmative character. This is found in the breaking down and resorption of the lens, — habitually in Proteus, and probably occasionally in Typhlogobius, — possibly in the excess of pigment in the iris and pigment layer of the retina, and particularly in its occasional presence in the hyaloid membrane of the Typhlogobius eye, while no evidence of actual degeneration in the retina appears in connection with these. The possible case of a degenerating retina in Typhlogobius is neglected in this consideration, since, as pointed out, the lens being absent in the same eye, it is immaterial whether it be considered or not.

The Integumentary Sense Papillæ.

1. These have been considered only so far as pertains to the question whether they have been developed to compensate the rudimentary condition of the eyes; and it is concluded that such is not the case.

2. The facts that lead to this conclusion are the presence in several closely related genera — four at least — of the tactile papillæ with the same distribution as those of Typhlogobius, and in addition to this, on parts of the body where they are not found at all in Typhlogobius, excepting in the smallest specimens; and that the papillæ that are present in Typhlogobius are not more highly developed than those of corresponding regions in related genera.

3. In comparing the several species of blind fishes with a view to determining under what conditions the tactile sense does become developed to compensate the loss of sight, it is concluded that, while the greater activity of the cave blind fishes might explain their more highly developed tactile papillæ, this cannot be affirmed as a general law, since other blind fishes (as some at least of the deep-sea forms and probably also the blind Silurids) are without tactile papillæ, while we have no reason to suppose them less active than the cave fishes. It is necessary to have more knowledge than is yet possessed of the mode of life of the various blind forms before this question can be fully answered.

The Integument.

1. This structure has been studied with reference to the pigment contained in it, and the pink color of the living fishes.

2. Very nearly if not fully as much pigment is present in the largest as in the smallest specimens, the lighter color of the former being due to the obscuration of the pigment by a thickening of the sub-epidermal tissue between the pigment and the epidermis.

3. The pink color of the living animals is due, in great part at least, to a highly abnormal development of blood-vessels in the sub-epidermal portion of the integument.

4. So far as it has been possible to determine, this vascularity of the skin is unique in this fish.

5. The most probable explanation found of this condition is that it is for the purpose of cutaneous respiration.

University of California, Berkeley,
July 4, 1892

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ABBREVIATIONS.

bac.	Rods of the retina.
bac. cla.	Knobbed or club-shaped rods.
chr.	Choroid.
chr.-cpl.	Chorio-capillaris.
cl., cl.', cl."	Refractive cells of retina as they appear at different foci.
cl. con't.	Cells in connective tissue.
cl. gn.	Ganglion cells.
cl. gn.'	Ganglion cells showing processes.
cl. mt.	Mantle cells.
cl. sns.	Sense cells.
con't. tis.	Connective tissue.
cp. sng.	Blood corpuscle.
crn.	Cornea.
crt.	Cartilaginous portion of sclera.
drm.	Derma.
ec'drm.	Ectoderm.
ex.	Outermost portion of pigment layer of retina.
fbr. Müll.	Müller's fibres.
fos.	Flask-shaped pit in papilla.
ful.	Tangential fulcrum cells.
glb. pig.	Pigment nodules, clusters, balls, etc.
gl. chr.	Choroid gland.
gl. muc.	Mucus glands.
i.	Innermost ends of the processes of pigment layer of retina fused together.
ir.	Iris.
leu'cy.	Leucocytes in retina.
lig. ann.	Non-pigmented elements of the iris, ligamentum annulare.
lns.	Lens.
m.	Middle portion of the processes not fused together.
mb. l.n. ex.	Membrana limitans externa.
mu.	Muscle.
nl. ba.	Basal nuclei. (See p. 65.)
n. opt.	Optic nerve.
n. pap.	Nerve to papilla.
ob. ex.	External oblique muscle.
or. ser.	Ora serrata.
pap.	Papilla.
pig.	Pigment.
pig.'	Pigment behind cornea.
pig."	Pigment in place of lens (Fig. 7) and (Fig. 12) hyaloid membrane (?).
pig."'	Pigment surrounding optic nerve.
pig. rtn.	Pigment of retina.
po.	Pore in epidermis.
pr'c.	Processes of the pigmented layer of the retina.
rt.	Rectus muscles.
rtn.	Retina.
scl.	Sclera.
set. cl. sns.	Bristles of sense cells.
spa.	Spaces in the connective tissue over the eye.
spng-bl.	Spongioblasts.
st. bac. con.	Layer of rods and cones.
st. con't.	Stratum of formed connective tissue.
st. fbr. opt.	Optic fibre layer.
st. lac.	Stratum lacunosum.
st. nl. ex.	External nuclear layer.
st. nl. i.	Internal nuclear layer.
st rtl ex.	External reticular layer.
st. rtl. ex.'	Non-nucleated spaces in *st. rtn.'*, the beginning of external reticular layer.
st. rtl. i.	Neurospongium (inner molecular layer) = inner reticular layer (preferable).
st. rtn.'	Undifferentiated layer of retina.
tt	Non-nucleated tract between sense cells and mantle cells.
va. sng.	Blood-vessels.

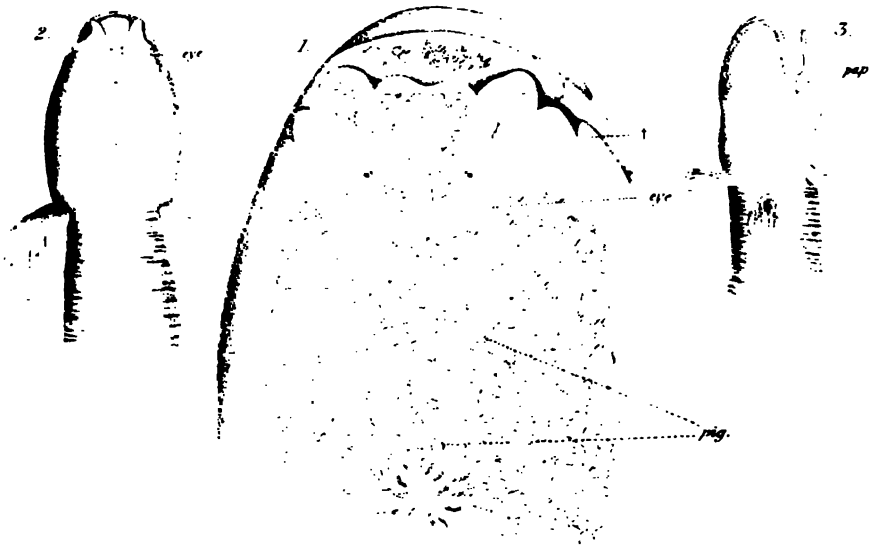
PLATE I.

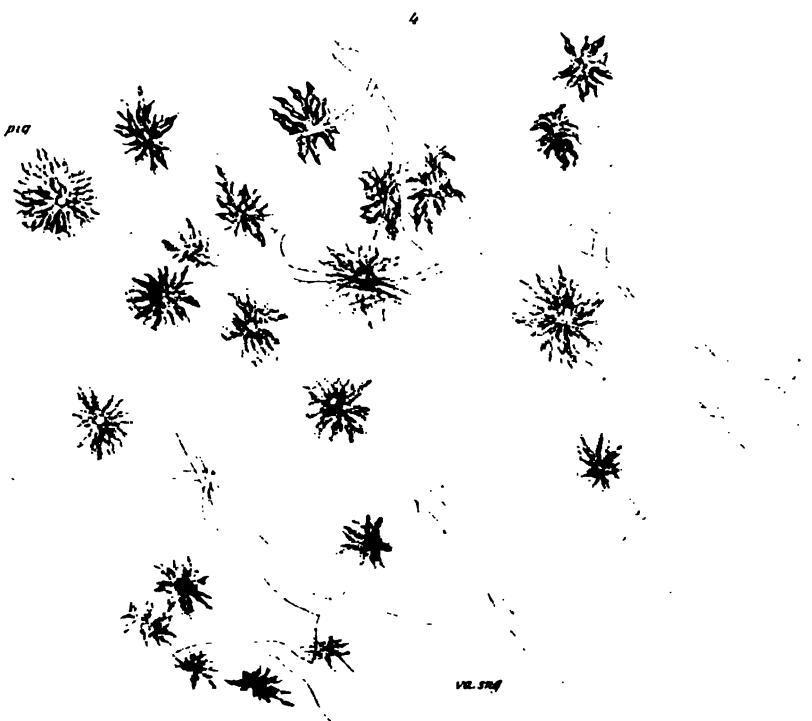
Fig. 1. View of the dorsal side of the head of an individual 19 mm. long, showing the distribution of the pigment cells, the folds of the skin, and the eyes. × 18.

" 2. Similar view of an individual about 55 mm. long. × 2½.

" 3. An individual of the same size seen from the ventro-lateral side. × 2.

" 4. Nitric-acid glycerine preparation of integument from the dorsum of the head of a specimen 72 mm. long, showing the blood-vessels and the pigment cells. — Surface view. × 59.





W. E. Ritter del.

Mass. Lith. Boston

PLATE II.

Fig 5. Meridional vertical section of an eye from a specimen about 50 mm. long. × 150. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 6. Meridional section of an eye without a lens. Specimen 63 mm. long. × 88.

" 7. The section, not quite meridional, is from the same eye from which Figure 6 is taken, and is given to show the pigment mass (*pig''*) in the place of the lens. Consequently only the pigmented portion of the eye is drawn. × 115.

" 8. A dissected acetic-acid glycerine preparation to show the eye muscles and optic nerve. × 60.

" 9. Section of the integument from the dorsum of the head perpendicular to the surface, from an individual 19 mm. long. × 450.

" 10. Section similar to the one shown in the preceding figure, but from an individual 72 mm. long. × 450.

" 11. Preparation similar to the one shown in Figure 4 (Plate I.), but from the side of the body. × 63.

" 12. Section, not quite meridional, from an individual 60 mm. long. × 115.

" 13. The pigmented portion of the retina and choroid, from the same eye. × 230. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 14. A small portion of the pigment layer of the retina, and the choroid gland with the optic nerve passing through it. Specimen 63 mm. long. × 300.

" 15. A small portion of the retina, showing the optic nerve passing through it. Same eye as that shown in the preceding figure. × 300.

" 16 The iris and the adjacent parts; same eye as that shown in Figure 5. × 350.


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PLATE III.

Fig. 17 Meridional vertical section of the eye of a specimen 19 mm. long. × 230. *a*, connective-tissue strands (see text, pp. 57, 58); *β*, ciliary processes ? (see text, pp. 63, 64).

" 18. Small portion of the retina of the eye shown in Figures 5 and 16. × 980.

" 19. A small portion of a section of the retina near the ora serrata from the eye having no lens. × 700.

" 20. Section of the retina of *Clevelandia*.

" 21. A small portion of the retina of the eye shown in Figure 13. × 350.


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PLATE IV.

Fig. 22. Rods from the same eye as the preceding (Fig. 21); *a'*, *b'*, outer members; *a''*, *b''*, inner members; *c*, portion of outer member showing the more transparent round spots. × 720.

" 23. Section of a tactile papilla from the median lower-jaw series of a specimen about 50 mm. long. The section is not quite parallel to the long axis of the papilla, and this accounts for its appearing not to extend fully through to the deep surface of the epidermis. × 720.

" 24. Section of another papilla of the same series, same specimen as the preceding. × 350 about.

Note. — The leader from *va. sng.* has neither the right direction nor sufficient length to reach the blood-vessel in the axis of the papilla.

" 25. Diagram showing the arrangement and relative size of the papillæ found on the right side of the head of a specimen 19 mm. long.

" 26. Section of a papilla of the median lower-jaw series of *Lepadogaster* × 340.

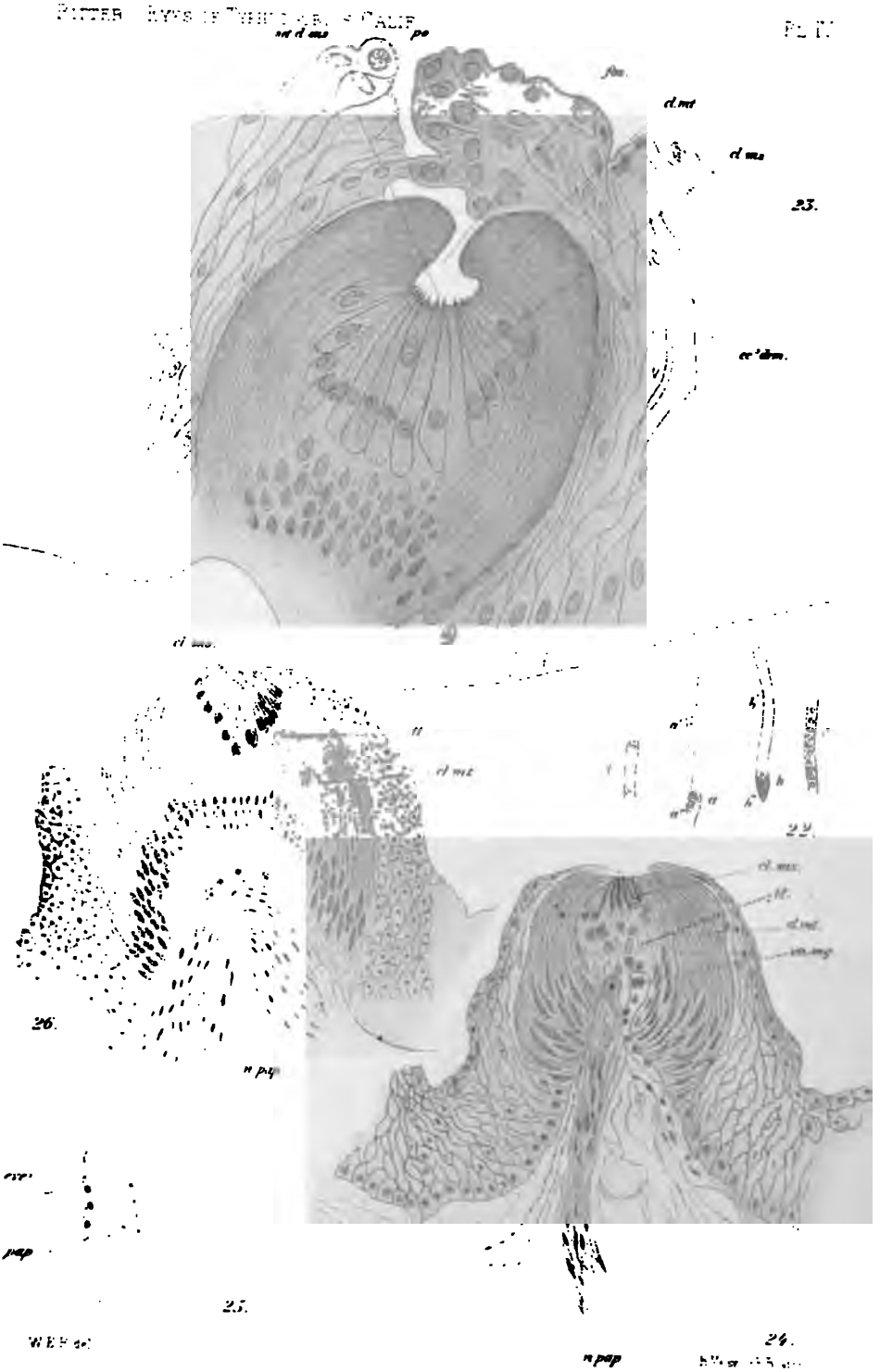
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PLATE II.

Fig 5. Meridional vertical section of an eye from a specimen about 50 mm. long. × 150. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 6. Meridional section of an eye without a lens. Specimen 63 mm. long. × 88.

" 7. The section, not quite meridional, is from the same eye from which Figure 6 is taken, and is given to show the pigment mass (*pig.''*) in the place of the lens. Consequently only the pigmented portion of the eye is drawn. × 115.

" 8. A dissected acetic-acid glycerine preparation to show the eye muscles and optic nerve. × 60.

" 9. Section of the integument from the dorsum of the head perpendicular to the surface, from an individual 19 mm. long. × 450.

" 10. Section similar to the one shown in the preceding figure, but from an individual 72 mm. long. × 450.

" 11. Preparation similar to the one shown in Figure 4 (Plate I.), but from the side of the body. × 63.

" 12. Section, not quite meridional, from an individual 60 mm. long. × 115.

" 13. The pigmented portion of the retina and choroid, from the same eye. × 230. The fold in the pigment layer of the retina is indicated at *. (See text, p. 63.)

" 14. A small portion of the pigment layer of the retina, and the choroid gland with the optic nerve passing through it. Specimen 63 mm. long. × 300.

" 15. A small portion of the retina, showing the optic nerve passing through it. Same eye as that shown in the preceding figure. × 300.

" 16 The iris and the adjacent parts; same eye as that shown in Figure 5. × 350.


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gl. chr.
Mass. Inst. Boston

PLATE III.

Fig. 17. Meridional vertical section of the eye of a specimen 19 mm. long. × 230. *a*, connective-tissue strands (see text, pp. 57, 58), *β*, ciliary processes ? (see text, pp. 63, 64).

" 18. Small portion of the retina of the eye shown in Figures 5 and 16. × 980.

" 19. A small portion of a section of the retina near the ora serrata from the eye having no lens. × 700.

" 20. Section of the retina of *Clerelandia*.

" 21. A small portion of the retina of the eye shown in Figure 13. × 350.

vor. Die Diagnose der Gattung lautet: (18—) 20 Fühler; keine Fühlerampullen; Steincanal an, aber nicht in die Körperwand tretend; Bauch etwas abgeflacht; kleine, gleichartige, zahlreiche Füsschen sind über den ganzen Körper gleichmässig vertheilt; Genitalschläuche nur in einem (linken) Büschel; After ventral oder subventral, ohne Auszeichnung; Kalkkörper in der Haut und in den Füsschen vorhanden.

Die Merkmale der neuen Gattung *Meseres* mit der einen Art: *M. macdonaldi* n. sp. sind die folgenden: 15 Fühler; keine Fühlerampullen; Steincanal?; Körper niedergedrückt mit abgeflachter Bauchseite, deren Rand ringsum von einer einfachen Reihe feiner Füsschen wie von einem Randsaume besetzt ist; ausserdem unregelmässig (?) über den ganzen Körper vertheilte Füsschen (? Papillen); Genitalschläuche in zwei Büscheln (einem rechten und einem linken); After ventral, ohne Auszeichnung; Haut ohne Kalkkörper.

Die Unterfamilie der Synallactinae umschliesst demnach Formen, welche in dem Mangel der Fühlerampullen, im Verhalten des Steincanals und, wie hier hinzugefügt werden kann, auch in dem Fehlen eines Wundernetzes von den Aspidochiroten zu den Elasipoden hinüberleiten und so die schon vor einiger Zeit von mir geäusserte Ansicht bestätigen, dass die Elasipoden Abkömmlinge von Aspidochiroten sind.

II. ELASIPODA.

1) **Psychropotinae.** Die sechs vorliegenden Arten sind mit Ausnahme einer einzigen, der *Benthodytes sanguinolenta* Théel, sämmtlich neu. Eine gehört ebenfalls zur Gattung *Benthodytes: B. incerta.* Die vier anderen vertheilen sich auf die Gattungen *Psychropotes: Ps. raripes* und *Ps. dubiosa* und *Euphronides: E. tanneri* und *E. verrucosa.*

Euphronides tanneri n. sp. schliesst sich nahe an die typische Art der Gattung: *E. depressa* Théel an, unterscheidet sich aber durch die grössere Zahl der Rückenpapillen und durch stärkere Bedornung der vierarmigen Kalkkörper. Auffallend ist ihr Reichthum an Kalkkörpern in den inneren Organen, namentlich in der Wand der Genitalorgane, des Darmes und der Darmblutgefässe. *Euphronides verrucosa* n. sp. unterscheidet sich von *E. depressa* und *E. tanneri* schon durch die zahlreichen Warzen, mit welchen der Rücken des Rumpfes und Saumes übersät ist; dazu kommt eine geringere Abflachung des Körpers, eine geringere Breite des Saumes, eine andere Zahl der Fühler und Rückenpapillen sowie Form und Grösse der Kalkkörper.

Psychropotes raripes n. sp. ist durch die geringe Zahl (7—8) der freien

Gattung *Scotoanassa* liegen mehrere Exemplare und Bruchstücke vor, welche zur Aufstellung einer neuen Art *Scotoanassa gracilis* zwingen, deren Diagnose die folgende ist: Körper etwa dreimal so lang wie breit, nach hinten etwas verjüngt. Vordersaum (= Nackensegel) und Hintersaum durch einen Seitensaum verbunden; Vordersaum mit vier Zipfeln, von denen zwei vorwärts, zwei seitwärts gerichtet sind; Hintersaum zu einem unpaaren, nach hinten gerichteten Zipfel verlängert. Mund ventral und schräg nach hinten gestellt, am Ende eines kurzen, nach hinten abgeknickten, vordersten Rumpfabschnittes. Endscheibe der (10!) Fühler rundlich mit zahlreichen, winzigen Papillen. Füsschen gross, nur unten an den Seitentheilen des Hintersaumes angebracht, jederseits in der Zahl fünf. Haut sehr zart, etwas durchscheinend; ihre vierarmigen Kalkkörper zahlreich, aber zart und mit schlanken, nur sehr schwach bedornten Aussenfortsätzen, die fast doppelt so lang sind wie die gleichfalls nur sehr schwach bedornten Arme selbst.

III. PELAGOTHURIIDAE.

Unter allen vom Albatross erbeuteten Formen ist eine merkwürdige Art am auffälligsten und interessantesten, welche sich in Bau und Lebensweise so sehr von allen bisher bekannten Holothurien unterscheidet, dass sie nicht nur als Vertreter einer neuen Gattung sondern auch einer neuen Familie betrachtet werden muss. Sie führt ein pelagisches Leben und zeichnet sich in bemerkenswerthester Weise durch die Ausbildung eines besonderen Schwimmapparates aus, der in einer am Rande in lange Strahlen ausgezogenen Scheibe besteht, welche im Umkreis des Fühlerkranzes angeordnet ist und in seiner Form etwa an die an ihrer Basis durch eine Schwimmhaut verbundenen Arme mancher Tintenfische erinnert. Ich beschränke mich hier darauf eine kurze Diagnose der Familie, Gattung und Art zu geben und daran einige Worte über die Verwandtschaft des wunderbaren Thieres zu knüpfen, bei dessen Anblick man zunächst an manches Andere eher als an eine Holothurie denkt.

Familie **Pelagothuriidae.** Füsschen (und Ambulacralpapillen) fehlen. Mund und After terminal. Körper drehrund, rings um den Fühlerkranz zu einer dünnen, an ihrem Rande zu langen Strahlen ausgezogenen Scheibe ausgebreitet. Die Fühlercanäle entspringen aus den wohlentwickelten Radialcanälen und entsenden an der Fühlerbasis je einen (wahrscheinlich einer Fühlerampulle homologen) Canal in die Scheibe; diese Scheibencanäle verlaufen in radiärer Richtung zur Peripherie der Scheibe und treten in je einen Strahl des Scheibenrandes ein

um ihn bis zur Spitze zu durchziehen. Längsmuskeln der Körperwand einfach; Rückziehmuskeln fehlen; Quermusculatur in den Radien unterbrochen. Weder Kiemenbäume, noch Wimperorgane, noch Cuvier'sche Organe sind vorhanden. Genitalorgane rechts und links vom dorsalen Mesenterium.

Pelagothuria n. g. 13—16 Fühler und ebenso viele Scheibencanäle sind vorhanden. Die Fühler sind am Ende zweitheilig und ebendort mit winzigen Papillen besetzt. Keine Spur eines Kalkringes. Steincanal in der Einzahl, dicht vor dem Genitalgang zur Haut aufsteigend und direct nach aussen mündend. Jederseits ein traubenförmiges Genitalorgan, das linke oft viel kräftiger entwickelt als das rechte. Kalkkörper fehlen sowohl der Haut als allen inneren Organen.

Pelagothuria natatrix n. sp. Haut dünn, weich, etwas durchscheinend, violett bis purpurn gefärbt. Rumpf etwa dreimal so lang wie dick, nach hinten verjüngt und abgerundet. Länge des Körpers einschliesslich der Fühler bis 47 mm.; Dicke des Rumpfes bis 13 mm.; Durchmesser der Schwimmscheibe bis 35 mm.; Länge der Scheibenstrahlen bis 50 mm.

Im Mangel der Füsschen stimmt die neue Familie der Pelagothuriiden mit den Synaptiden und den Molpadiiden überein, unterscheidet sich aber von diesen durch das Fehlen der Kiemenbäume, von jenen durch den Besitz von Radialcanälen, den Ursprung der Fühlercanäle aus diesen Radialcanälen, die Unterbrechung der Quermusculatur der Körperwand, den Mangel der Wimperorgane. Das Fehlen der Kiemenbäume verweist die Pelagothuriiden unter den actinopoden Holothurien, zu denen sie zweifellos gehören, in die Nachbarschaft der Elasipoden, von denen sie aber wieder durch den Mangel aller Füsschen (und Ambulacralpapillen) geschieden sind. Ich glaube in ihnen Abkömmlinge von Elasipoden sehen zu müssen, die sich aus den Verhältnissen der Tiefsee zu Bewohnern der oberflächlichen Meeresschicht heraus- und emporgearbeitet und dem pelagischen Leben durch Ausbildung eines Schwimmapparates angepasst haben.

IV DENDROCHIROTAE.

Die Dendrochiroten sind durch neun Arten vertreten, die zu fünf Gattungen gehören; darunter befinden sich eine neue Gattung und sieben neue Arten. Eine Art *Phyllophorus aculeatus* n. sp. stammt nicht aus der Tiefe, sondern von der Küste von Panama. Die übrigen Arten sind Tiefenbewohner aus den Gattungen *Psolus* (vier Arten), *Psolidium*

(zwei Arten), *Cucumaria* (eine Art) und *Sphaerothuria* n. g. (eine Art). Von den vier *Psolus*-Arten ist eine nur in einem jugendlichen, nicht sicher bestimmbaren Exemplare vorhanden. *Psolus pauper* n. sp. zeichnet sich durch völligen Mangel von Kalkkörperchen in der Haut der Sohle aus und steht im Übrigen den Arten *squamatus* und *fabricii* nahe. *Psolus digitatus* n. sp. hat ebenfalls den Habitus der beiden eben genannten Arten, unterscheidet sich aber durch die Gestalt der Fühler, welche einfach fingerförmige, unverästelte Schläuche darstellen; die Fühler haben demnach hier ihre jugendliche Form dauernd festgehalten — ein Fall, den wir bis jetzt nur bei den Molpadiiden-Gattungen *Eupyrgus* und *Hoplodactyla* kannten. *Psolus diomedeae* n. sp. schliesst sich durch die deutliche Ausbildung von je fünf interradialen Oral- und Analplatten an *Ps. antarcticus*, *tuberculosus* und *ephippifer* an, von denen er sich aber in anderen Merkmalen hinreichend unterscheidet.

Die beiden neuen *Psolidium*-Arten, *panamense* und *gracile*, geben Veranlassung die Diagnose der Gattung *Psolidium* einer Revision in dem Sinne zu unterwerfen, dass sie nunmehr lautet: "Zehn Fühler (die beiden ventralen kleiner als die übrigen); mittlerer Abschnitt des Triviums zu einer deutlich umgrenzten Sohle abgeflacht und hier mit gut entwickelten, auf die Ambulacren beschränkten Füsschen besetzt; auf der übrigen Körperoberfläche kleinere oder zu Papillen verkümmerte Füsschen, welche entweder überall zerstreut stehen oder sich an den Körperenden auf die Radien beschränken." Von der so gefassten Gattung *Psolidium* unterscheidet sich *Theelia* lediglich durch die Zahl (15) der Fühler. Zu *Psolidium* wird auch die Théel'sche Art *Psolus brasiliensis* gerechnet, so dass *Psolidium* nunmehr vier Arten: *dorsipes* Ludw., *brasiliense* Théel, *panamense* und *gracile* umfasst. Die *Psolidium*-Arten lassen sich als werdende, in Bildung begriffene *Psolus*-Arten ansehen. Die Formenreihe, welche sich von *Cucumaria* (und *Thyone*) beginnend durch *Colochirus* zu *Psolidium* und von hier zu *Theelia* und schliesslich zu *Psolus* verfolgen lässt, begründet die Ansicht, dass die Gattung *Psolus* keine alterthümliche und ursprüngliche, sondern eine verhältnismässig junge, vielleicht eine der jüngsten unter allen Dendrochiroten ist.

Die *Cucumaria abyssorum* Théel wurde in 64 Exemplaren aus Tiefen von 905—2232 Faden erbeutet, welche lehren, dass die var. *hyalina* Théel jugendliche, dagegen die var. *grandis* Théel alte erwachsene Thiere derselben Art darstellt.

Als die interessanteste aller bis jetzt ausgefundenen Tiefsee-Dendrochiroten erscheint die neue Gattung *Sphaerothuria* mit der einen Art: *Sph. botentaculata* n. sp. Dieselbe hat eine fast kugelrunde Gestalt, und

ist mit grossen Platten bepanzert, welche je einen kräftigen, frei hervorstehenden Stachel tragen. Die Fühler haben wie bei *Psolus digitatus* die einfach cylindrische, jugendliche Form bewahrt. Von den zehn Fühlern anderer Dendrochiroten sind die beiden ventralen, die bei jenen oft sehr viel kleiner sind als die übrigen, vollständig geschwunden. Von den acht übrig gebliebenen sind sechs (vier dorsale und zwei ventrale) verkümmert, dagegen nur zwei (ein rechter und ein linker) wohl entwickelt. Am Kalkring ist jederseits das ventrale Interradialstück mit dem seitlichen ventralen Radialstück zu einem anscheinend einheitlichen Stücke zusammengedrängt. Die ungemein kleinen Füsschen sind auf die Radien beschränkt; ihre Füsschencanäle durchbohren die Platten des Hautpanzers. Aus einem Vergleiche mit *Cucumaria* (*Echinocucumis*) *typica* (Sars) geht hervor, dass die *Sphaerothuria* aus der *Echinocucumis*-Gruppe der Gattung *Cucumaria* abzuleiten ist.

V. MOLPADIIDAE.

In der Sammlung sind sechs Arten vertreten, von denen nicht weniger als vier neu sind. Eine Art: *californica* n. sp. gehört zur Gattung *Caudina*, drei Arten: *violaceum* (Stud.), *granulatum* n. sp. und *intermedium* n. sp. gehören zur Gattung *Trochostoma*, zwei Arten: *danielsseni* Théel und *spinosum* n. sp. zur gattung *Ankyroderma*. Die *Caudina californica* ist durch ihre Kalkkörper scharf unterschieden von den bisher bekannten *Caudina*-Arten. *Trochostoma violaceum* (Stud.) und *Ankyroderma danielsseni* Théel konnten bis jetzt als rein antarktische Formen angesehen werden, während sich nunmehr herausstellt, dass sie in tiefem kalten Wasser nordwärts den Äquator überschreiten. Dass dieses Vordringen in tropische Meeresgebiete Hand in Hand geht mit dem Herabsteigen in grössere, kalte Tiefen lässt sich besonders bei *Trochostoma violaceum* nachweisen. Die neue Art *Trochostoma granulatum* ist durch ihre Kalkkörper characterisiert und entbehrt wenigstens in den vorliegenden Exemplaren der "weinrothen Körperchen." Auch die andere neue *Trochostoma*-Art: *intermedium* ist durch ihre Kalkkörper gekennzeichnet, welche ihr eine vermittelnde Stellung zwischen den arktischen Arten: *Tr. arcticum*, *boreale*, *thomsonii* und dem antarktischen *Tr. antarcticum* anweisen; an einem Exemplare konnte die innere Organisation genauer untersucht werden. Von dem bis jetzt nur nach einem einzigen Exemplare aus der Ausbeute des *Challenger* bekannten *Ankyroderma danielsseni* sind im Ganzen 29 Exemplare vorhanden, welche eine Bestätigung und Ergänzung der Théel'schen Angaben ermöglichten. In ihrer geographi-

schen Verbreitung bietet diese antarktisch-pacifische Art ein Gegenstück zu der arktisch-atlantischen *A. jeffreysii*, ohne indessen, wie Théel vermuthete, nur eine Varietät der letzteren zu sein. Die neue Art *Ankyroderma spinosum* unterscheidet sich von der übrigens nahe verwandten *A. danielssenii* vorzugsweise durch die Kalkkörper der Rumpfhaut und die verhältnismässig grössere Länge des Schwanzes.

VI. SYNAPTIDAE.

Nur eine Art *Synapta abyssicola* Théel liegt in Bruchstücken aus 1672 und 1772 Faden Tiefe vor, welche in ihren Kalkkörpern nur insofern eine Abweichung von den typischen Exemplaren zeigen als die Ankerarme keine Zähnchen besitzen. Wegen dieses Unterschiedes geben die vorliegenden Bruchstücke einstweilen zur Aufstellung einer besonderen Varietät: *pacifica* Veranlassung. Sie gestatten ferner nähere Mittheilungen über den anatomischen Bau dieser Art, von der bis jetzt einzig und allein die Kalkkörper bekannt waren.

Bonn, den 6. April, 1893.

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AT HARVARD COLLEGE.
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THE DEVELOPMENT OF THE SCALES OF LEPIDOSTEUS.

BY W. S. NICKERSON.

WITH FOUR PLATES.

CAMBRIDGE, U. S. A.:
PRINTED FOR THE MUSEUM.
JULY, 1893.

No. 5. — *The Development of the Scales of Lepidosteus.* By W. S. Nickerson.[1]

The scales of Lepidosteus have been studied by several investigators. Their most prominent peculiarity is the possession of a hard, smooth, nearly homogeneous outer layer, which in the adult condition lies free to the exterior not covered by other tissue. The question of most immediate interest concerning the scales is the one in regard to the source and nature of this outer layer. The view which has been generally held concerning it is that recently maintained by Oscar Hertwig ('79), who believes that it is a true enamel layer derived from the overlying epidermal tissue.

The more recent studies of Klaatsch ('90) seem to contradict this conclusion by showing that it has a dermal origin. Closely connected with the question concerning this layer, and in part dependent upon the answer found for it, is that of the relationship existing between the Ganoid scale and the scales of Selachians, Teleosts, and Dipnoi. Additional interest is also given to this inquiry by the fact that it has a bearing upon the question of the relation of scales to teeth.

The writers who up to this time have investigated the scales of Lepidosteus have, with one exception, had only adult material for study, and therefore their conclusions regarding the outer layer were necessarily drawn chiefly from the physical properties of the finished scale. Since in the adult the tissue has disappeared from the outer surface of the scales, it is evident that the source of the problematical outer layer can be determined only by the study of young fishes in which the scales are in process of formation, and still covered by the tissue which produces them.

Klaatsch ('90) in his study of material from a single young gar-pike made some very interesting and important observations, which, if confirmed by subsequent investigations, must overthrow the idea of Hertwig, that the outer layers of the ganoid scale are directly homologous with the enamel of the teeth of higher vertebrates.

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXVI.

By the study of abundant material from several (ten) different fishes of various ages and sizes, I have endeavored to trace the course of development with sufficient thoroughness to settle the origin of the layer now in dispute, and if possible to throw some light upon the homologies of the scales of the Ganoids. For the most part my observations lead me to conclusions in agreement with those of Klaatsch, although in regard to some points I am unable to coincide with his views.

For the greater part of the material used I am indebted to Dr. Edward L. Mark, who very kindly placed at my service his own supply. These fishes had been reared by him in aquaria from eggs collected at Black Lake, N. Y., in the spring of 1882. They had been killed at intervals by various fixing reagents, as indicated in the table following, and carefully preserved in alcohol. The histological conditions were very faithfully preserved in all except one specimen. This, the largest and oldest fish of the lot, had died in the aquarium after attaining an age of fifty-two months and a length of thirty centimeters. When found it could have been dead but a few hours at most, and was at once preserved in alcohol. On studying this fish I found the scales in a most interesting stage of development, but unfortunately the epidermis had so far degenerated that it was impossible to make out anything of importance concerning its relation to the scale. I was moreover somewhat apprehensive lest the confinement in which these fishes had been reared, together with the handling and other unnatural treatment to which they had been subjected, might have rendered the conditions of the scales found in this and the other larger fishes abnormal to some extent.

I was unable to obtain at once healthy material of the proper age to show the later stages of growth, and to this fact is due a considerable delay in the completion and publication of the results of my work. The missing later stages were supplied by material from two young gar pikes which Mr. S. P. Bartlett of the Illinois State Fish Commission obtained and very kindly sent me. They were killed according to my direction by immersion in strong alcohol, a method that is very satisfactory for epidermal and dermal tissues, and which has the advantage over acid killing-fluids of leaving calcareous structures quite unaffected. For other material which I have studied I am indebted to Prof. E. A. Birge of the University of Wisconsin, and through Dr. Mark to Prof. Jacob Reighard of the University of Michigan. The material from both of these sources had been killed in alcohol.

To all of these gentlemen I wish to express my gratitude, and especially to Dr. Mark, not only for his liberal supply of material

which it had cost him much time and labor to obtain, but also for his direction and many valuable suggestions.

TABULATED LIST OF FISHES STUDIED.

Length. mm.	Age. Months.	Killing Reagent.	Condition.	Received from
145	18+	Merkel's fluid.	Local aggregations of spongy connective tissue.	Dr. Mark.
115	18	$HgCl_2$ (hot).	Bony scale beginning to be formed.	" "
150	18+	Merkel's fluid.	Spines being formed.	" "
160	19	90 per cent alcohol.	Few spines.	" "
175	24	Picro-sulphuric acid.	Edges of scale beginning to overlap.	" "
190	35	2 per cent chromic + acetic (few drops).	Mature spines all over scales.	" "
287	?	Alcohol.	Spines all over scale; no ganoin layer.	Prof. Birge.
300	52	Died. 90 per cent alc.	Epidermis degenerated; thin ganoin layer.	Dr Mark.
300	?	Alcohol.	Spines on edges; thin ganoin layer.	Mr S. P Bartlett.
460	?	Alcohol.	Few spines on edges; thicker ganoin layer	Prof Reighard.

The method used has been chiefly the preparation and study of series of sections. In all except very young stages it was necessary to decalcify the material before it could be sectioned, and even after decalcification sections in most cases could not be cut thinner than 15 μ, and often in the later stages it was necessary to make them between 20 and 30 μ thick. For decalcifying I used 90% alcohol to which was added a small quantity of 10% hydrochloric acid (in the ratio of about 3 to 1). The tissue was usually left in this acid alcohol twenty-four hours or more, and then soaked in several changes of fresh alcohol to remove all traces of the acid before staining. Sections prepared by grinding down scales have also been studied, as well as scales freed from the soft tissues by treatment with caustic potash. Only by the use of the latter reagent was I able to get a satisfactory knowledge of the spines which cover the scale in its immature state.

The stains which have given the best results are Boehmer's alum hæmatoxylin and Kleinenberg's hæmatoxylin. As a nuclear stain the

former is much the better; the latter is especially useful in the study of the glands of the epidermis and in bringing cell membranes into prominence.

The young Lepidosteus in which I found the earliest indication of the formation of scales was about 145 mm. long and a little over eighteen months old. Klaatsch has stated that the scales appear upon the dorsal side of the body earlier than upon the ventral, and as the material studied was taken in this specimen (as in most cases) from near the ventral line, it is probable that the scales begin to form upon the dorsal portion of the body at a somewhat earlier age.

Before the beginning of the formation of the scales the integument is about 225 μ thick. The epidermis is nearly twice as thick as the dermis and is made up of numerous layers of spheroidal or cuboidal cells (Fig. 1). The cells of the deepest layer are somewhat elongated in a direction perpendicular to the surface, and consequently have the appearance of indistinctly columnar epithelium.

There are two kinds of glandular structures present in the epidermis. Those of one kind have a spherical, or more often ovoid or oblong form, with the greater axis perpendicular to the surface of the body, and appear in sections as spaces of corresponding shape. The long diameter in the larger of these spaces is not infrequently (Fig. 1) from one half to two thirds the thickness of the epidermis (75–100 μ).

The glands are quite irregularly distributed, some areas being only very meagrely provided with them, while in others they are so crowded as to leave little more than thin filmy partitions between them. Sections parallel to the surface in such areas present a net-like appearance, the empty gland cells corresponding to the meshes. To each space there belongs a flattened nucleus, which is closely applied to the wall near its deep end. The whole structure is doubtless to be considered as a single cell which has taken on a secretive function, — a unicellular gland.

These glandular spaces sometimes appear empty, but are more often found partly filled by an indistinctly granular colorless substance (coagulum), probably precipitated by reagents from the fluid or semi-fluid secretion which they held during life (Plate I. Fig. 1, Plate II. Fig. 16). I do not find that these spaces have any means of communication with one another, and only very rarely do I find one having an opening to the exterior. Klaatsch has described these as mucous glands. I have no doubt that they are concerned in the production of

the slime by which the young "gars" are thickly covered. They are not, however, the only agents concerned in its production.

The epidermal glands of the second kind are considerably smaller than those already described; they are nearly spherical, and have an average diameter of from 18 to 25 μ. They do not appear to have been recognized by previous observers. Some of these lie in the deeper part of the epidermis, but much the greater number and the larger ones occur near the surface, where many of them open.

They stain deeply with Kleinenberg's and with Delafield's hæmatoxylin, but in all other stains used, even in other hæmatoxylin dyes, the nuclei alone are colored, and in this condition they can be distinguished from small glands of the first kind only by very careful observation. This probably accounts for their having been overlooked heretofore. In Kleinenberg's hæmatoxylin the whole gland takes a blue tint, while the wall presents a reticulated appearance due to an irregular network of lines of a much deeper blue color. This appearance is shown in Figure 2, *a–e*. The glands lying in the deeper part of the epidermis (*d*) take less color than those situated just below the surface (*c*); those which open at the surface vary much in the intensity of their coloring, the differences doubtless being due to the varying amounts of mucin contained in them. The distribution and peculiar staining qualities of these glands show that they originate in the deeper part of the epidermis and migrate to the surface, where their secretion is discharged.

Hæmatoxylin has long been known to stain mucus deeply. Hoyer ('90) found that basic stains are those which chiefly affect mucin, and that hæmatoxylin stains which contain alum act like basic stains. Of the four hæmatoxylin dyes which I have used, Kleinenberg's (basic) and Delafield's (alum) gave characteristic deep blue stains to these glands; Boehmer's (alum) and Ehrlich's (acid), on the other hand, gave pure nuclear stains. Hoyer imputed certain failures of hæmatoxylin stains to act in their normal manner to lack of "ripeness," and it is possible that this may be the reason for Boehmer's alum hæmatoxylin not coloring the mucin in this case.

At all events, I believe that the stains which I have obtained afford sufficient ground for declaring that these cells act as glands, and secrete the mucin element of the slime by which the young gar-pikes are thickly covered. The other and larger glands first described, which take only a nuclear stain with Kleinenberg's hæmatoxylin, must be considered to have the function of secreting some component of slime other than mucin.

The distribution of these mucous glands, like that of the kind first described, is somewhat irregular, and the two kinds are about equally numerous; those of the larger kind are, however, much more conspicuous by reason of their size. Both kinds of glands are found in the epidermis as long as it persists over the surface of the scales.

Chromatophores are abundant in the epidermis. They vary greatly in size and shape, and are found in all parts of the layer.

The boundary between epidermis and dermis is marked by the presence of a distinct basement membrane.

The dermis (Fig. 1), before it has begun to undergo modifications preparatory to the formation of the scales, is only about half as thick (75 μ) as the epidermis, and is composed of bundles of connective-tissue fibres which may be divided into three sets according to the directions in which they run. Two sets are parallel to the surface and diagonal to the axis of the body, the third is perpendicular to the directions of the other two. Of the first two sets, the fibres of one have a direction backward and ventrad parallel to the direction which the rows of scales will have later. The fibres of the other diagonal set cross these in such a way as to make the dorsal and ventral included angles a few degrees less than right angles, the anterior and posterior included angles being consequently a little greater than right angles. The fibres of the third set are much less numerous than those of either of the other two, and, as they extend perpendicularly through the dermis, serve to bind together the different layers. Nuclei are irregularly distributed among the fibres, as in ordinary connective tissue. Blood-vessels are numerous, and ramify chiefly in the outer part of the layer just beneath the basement membrane. Chromatophores are present, as in the epidermis, and are found mostly upon the two surfaces of the layer, being especially numerous at the deeper one (Fig. 1). Upon the outer surface they lie at nearly uniform distances apart (Fig. 4). Beside these color cells there is associated with them at the deeper surface of the dermis, between it and the musculature, quite a thick but very irregular sheet of finely granular white pigment. Concerning the origin of this pigment I have been able to learn nothing.

The first indication of the formation of scales is a change in the outer part of the dermis. There appear local thickenings of spongy tissue, which are made up of many nucleated cells and a small number of fibres lying among them without definite arrangement. These regions of modified dermis are abundantly supplied with blood vessels. At first

these thickenings are quite distinct from one another, being separated by tracts of unmodified tissue; thus each one resembles a very much flattened papilla.

A similar condition found in the early stages of the formation of the scales of Teleosts is described by Klaatsch ('90, p. 159) and by Hofer ('90, p. 111). Both of these authors regard these dermal thickenings in Teleosts as homologous with the dermal scale papillæ of the Selachians. This view receives a certain amount of support from the fact that in Selachians, Ganoids, and Teleosts the first indication of the formation of scales is the appearance of local elevations of the dermis in the form of papillæ. On the other hand, it is difficult to imagine any change due to increased local activity of the tissue taking place in the dermis without producing modifications resembling to some extent papillæ. That the scales of all the groups of fishes owe their origin primarily to the dermis seems therefore a sufficient explanation of the early appearance of these papilla-like local modifications of this layer, and not to require the assumption of any direct homology between the resulting structures. The fact that in Selachians the scale is formed over the surface of the papilla, while in Ganoids (Lepidosteus) and in Teleosts it arises in the midst of the mass of cells forming the elevation, is a fundamental difference not to be overlooked. Furthermore, at a later period in the formation of the scales of Lepidosteus there arise dermal papillæ just beneath the basement membrane, over the surface of which calcareous material is laid down to form spines. These receive an ectodermal enamel secretion over their tips, and later pierce the epidermis, and thus exactly resemble in all important features the spines of the placoid scales of Selachians. The formation of the spines in Lepidosteus has been described already by Klaatsch ('90, p. 130), and will be treated of more fully further on in this paper.

The condition found in Lepidosteus is intermediate between that presented by Selachians and that described in Teleosts. The presence of the spines enables us to say that the papillæ by which they are secreted, not the broader, earlier formed dermal thickenings, are the homologues of the papillæ formed in Selachians. As the early conditions found in Teleosts so closely resemble those in Lepidosteus, there can be no choice but to interpret these dermal thickenings as homologous with those of Lepidosteus. They cannot therefore be considered the homologues of the scale papillæ of Selachians, as maintained by Klaatsch and Hofer.

Hofer claims that in the trout the basal layer of cells of the epidermis

becomes modified over the scale papillæ to form an enamel membrane, though this never becomes functional and the cells soon lose their specialized character. Klaatsch studied the same form, and very positively denies that any such modification takes place. He says (p. 159): "Speciell die basale Epithelschicht lasst auch nicht die geringste Veränderung wahrnehmen." In view of this conflict of testimony, it seems more probable that the differences in the condition of the basal cells of the epidermis observed by Hofer were due to variations in different individuals than to changes normally taking place in the same individual.

At a little later period these areas of dermal thickening have extended laterally until their edges have become confluent, and the dermis may then be described as made up of two layers, an outer spongy layer and an inner fibrous layer, though no definite line of demarcation separates the two. This is the earliest stage described by Klaatsch. At the time when the formation of the scale begins, the spongy layer in its thickest parts is about equal in thickness to the deeper fibrous layer. The places in which scale formation is to take place are indicated by a somewhat greater thickness of the spongy layer.

The scale first appears (Fig. 3) as a thin sheet of calcareous secreted matter in the midst of the outer layer of the dermis. It is surrounded on all sides by the dermal cells, which lie thickly accumulated around it and cover it on its outer surface from two to four cells deep, completely separating it from the epidermis. Around its margin the cells lie closely packed, and at the posterior edge are particularly numerous. To these dermal secreting cells Klaatsch has given the name "Scleroblasten," a term which I shall adopt in referring to them.

The scale plate is not quite parallel with the surface of the body; its posterior margin is very slightly inclined outward, and with the scleroblasts around it forms a low elevation against the base of the epidermis (Fig. 3).

Secreted matter is not deposited where blood-vessels from below pierce the outer or scleroblastic dermal layer, and consequently openings through the scale result at such places. These persist to form the canals which pierce the middle area of the adult scale (Haversian canals of authors) The vessels which traverse them ramify upon the outer surface of the scale to supply nourishment to the overlying scleroblasts. No difference in character could be detected between the cells on the upper and those on the under side of the scale.

Almost as soon as the calcareous material of the scale begins to be laid down some of the surrounding scleroblasts become enclosed by it (Fig. 3). This process goes on hand in hand with the increase in the size of the scale, and as a result the scleroblasts are distributed through all parts of it. That the distribution is a fairly regular one may be seen from Figure 15 (Plate II.) and Figure 21 (Plate III.). In a scale from which the soft parts have been removed by treatment with caustic potash, the cavities occupied by these cells may be very distinctly seen. Each one has leading from it a small number of canals (canaliculi) which branch and traverse the scale to unite with similar canaliculi from the neighboring cavities. Thus the whole scale is traversed by a network of fine ramifying tubules connecting the osteoblastic cavities. As may be seen in section, however, all the canaliculi from a given cavity show a tendency to spread out in a plane parallel to that surface of the scale within which it has been buried, so that the cavities in most intimate connection are those which lie at the same distance below the surface. Thus the material of the scale is divided into more or less regular lamellæ of calcareous matter alternating with successive layers of cell cavities and their connecting canaliculi. These cavities are in communication with the exterior by means of canals which penetrate the scale and break up at their inner ends into fine tubules to join the canaliculi. They penetrate from both the upper and the lower surface, though much more abundantly from the lower (Plate II. Fig. 15, and Plate III. Fig. 21). At the opening of each of these canals at the surface of the scale there is a large cell (Plate I. Figs. 8 and 9, Plate III. Fig. 22, Plate IV. Fig. 23), from which a process extends into the lumen. These cells were called by Hertwig "Odontoblasten," and the canals occupied by their processes "Dentinröhrchen." I must, however, agree with Klaatsch that the names are poorly chosen, for the reasons set forth by him. The constant character of dentine, as the term has been used, is the absence of enclosed cells, and as the substance penetrated by the processes of these cells contains such elements (osteoblasts), it seems undesirable to call it dentine or the cells odontoblasts. Hertwig's nomenclature rests on an assumption of homology which has not been proved true. However, as these terms have been adopted in the literature, it is perhaps inadvisable to introduce new ones at this time. Besides the odontoblasts with their processes extending into the dentinal tubules which Hertwig describes and figures ('79, p. 5, Taf. III. Fig. 4), he mentions the presence of a granular substance partially filling the lumen of the canals. Klaatsch asserts that cells are present in the dentinal

tubules (p. 138). I have found by diligent searching a few cases in which, as stated by the latter author, cells seemed to be present in the lumen of the tubes. I have, however, observed other cases in which a flattened cell lay just at the side of the tube, but separated from its lumen by a thin layer of secreted material. I am therefore led by this and by the infrequency of the cases to believe that the cells apparently occupying the tube have a similar position, but that since they lie in radii of the tube perpendicular to the plane of the section they have the appearance of being in the lumen of the tube. Figure 8 will make this clear. At the opening of the tube is seen a cell which is apparently about to be enclosed between the secretion of the large odontoblast cell and the present wall of the canal. At a little later stage this, if seen in a plane at right angles to the present, would appear to lie in the lumen.

Each of these tubes is lined by a very thin secretion from the cell which extends into it, — a secretion of the same character as the material of the scale. In later stages, after the ganoin layer has begun to be formed, this sheath persists even after decalcification, when the ganoin is entirely destroyed (Plate IV. Fig. 23).

The scale increases both in thickness and in lateral extent by the deposition of new layers of material secreted by the surrounding scleroblasts. Thus the edges of adjacent scales come together, and finally overlap one another. Owing to the slight elevation of the posterior margin of the scale, previously mentioned, this edge of each scale overlaps the anterior edges of the adjacent posterior scales; for the same reason, each scale is in turn overlapped on its anterior edge by the posterior edges of the scales in front of it (Plate IV. Fig. 31).

Increase in thickness takes place upon both the outer and the inner surfaces, though much more rapidly upon the inner one. As the scale thickens inwardly, fibres which lay irregularly disposed beneath it in the spongy dermis are enclosed by the secretion. As the calcification extends deeper, the felted regularly arranged bundles of connective-tissue fibres of the deeper dermis are also enclosed, and help to make up the deeper part of the scale. These fibres extend across from one scale to another and so form a strong but flexible connection between adjacent scales. They are the "Schuppenligamente" of Hertwig. The ratio of outward to inward growth is shown by the arrangement of the layers of the scale (Plate II. Figs. 15, 16, and Plate III. Fig. 21). The oldest part of the scale is that in which the dentinal tubules from the opposite surfaces meet and break up into minute branches (Plate III. Fig. 21).

In their immature state, and before the outer layer has begun to be

formed, the scales bear upon their outer surface numerous slender conical spines or teeth. These were first described by Reissner ('59, p. 260). They stand up from the surface not quite perpendicularly, but have a slight inclination toward the tail (Plate I. Fig. 7, and Plate IV. Figs. 26, 28). They are transient structures, which frequently leave no trace of their existence in the adult scale. They begin to be formed when the scale is still comparatively thin (75–100 μ), and like it they owe their origin to the cells of the outer or scleroblastic layer of the dermis from which they are principally formed.

The first step in the formation of a spine is an increase in the number of the cells lying upon the upper surface of the scale just under the basement membrane. A thickening is thus formed which rises up against the base of the epidermis in the form of a papilla (Plate I. Fig. 5). The basal layer of epidermal cells becomes arched over it, and the columnar character of the cells much more pronounced. The papilla increases in height rapidly, pushing forward into the epidermis, with its point directed slightly caudad, but remaining at its base little if any larger than at first. The cells of which it is composed are the same in character as those overlying the scale; in the axis of the papilla they are crowded together without any definite arrangement, but at its periphery, where they adjoin the basement membrane which separates them from the epidermis, there is perceptible a certain degree of regularity in the arrangement of the nuclei; they lie rather closely appressed, being elongated radially to the axis of the cone.

After the papilla has attained a considerable height there appears upon its tip a thin crust of calcareous matter secreted by its cells; this gradually extends down over the sides, forming a conical cap (Plate II. Fig. 10), which is pushed forward by growth from below as the papilla increases in height. In the early stages of its formation, the papilla merely indents the lower surface of the epidermis, but as the point of the spine is pushed forward it causes a swelling upon the outer surface of that layer (Plate I. Figs. 5, 6). At the same time that this is taking place the thickness of the spine cap is being increased by the addition of new material from within. By the continuation of these processes the point of the spine is made to pierce the epidermis and so lie free to the exterior, while the basal end joins the scale already formed below. There is no joint or hinge of any kind at the place where the two unite, but the material of the spine is directly continuous with that of the outer part of the scale. The cells of the papilla are thus entirely shut off from the other scleroblastic cells which lie over the outer sur-

face of the scale except at one point, where a small opening persists through the side of the base of the spine at its junction with the scale (Plate I. Fig. 7, and Plate IV. Fig. 26).

I have as yet said nothing concerning an enamel layer upon the spines, because it could not be observed in any material of the stages described. Both Hertwig and Klaatsch assert that the points of the spines are covered by a cap of enamel. Reissner says (p. 260): "Die ganzen Stacheln scheinen übrigens auch einen dünnen Ueberzug von Schmelz zu besitzen." In scales which have reached the condition in which spines are present the thickness and hardness are such as to make section cutting impracticable, unless the tissue is first decalcified. In sections of decalcified scales no trace of an enamel cap is to be seen, nor is any space left between the point of the spine and the base of the overlying epidermis to indicate that anything has been lost. I was for some time inclined to believe that both Hertwig and Klaatsch were mistaken in asserting the presence of an enamel cap. In spines, too, which were broken off from scales which had been treated with caustic potash to remove the fleshy matter, there was evidently no enamel present. Such a spine is shown in Plate II. Fig. 11. Its cavity is seen to be continued up into the tip as a dendritic system of fine tubules (Dentinröhrchen of Hertwig), whose finest branches can be traced quite to the surface, and so preclude the possibility of an enamel cap being present.

I succeeded in learning the true condition only when, by the aid of a low power of the microscope, I watched the caustic potash slowly eat away the tissue from the surface of the spine bearing scale. As the epidermal tissue became clear and began to be dissolved, there could be seen supported in it minute scattered caps unconnected with the scale or the spines. With a little search, however, these caps were found in some cases resting directly over the points of spines, but raised slightly from them (Plate IV. Fig. 27). Similar conical caps were also found in the bottom of the watch-glass after the soft tissues had been entirely destroyed. Several of these loose caps were picked up and transferred to glass slides. On treating them with weak acid (2% HCl) their points quickly dissolved away, leaving the cap truncate (Plate II Fig. 12, a, b). The rest not only was not dissolved, but it showed no change when stronger acid (10% HCl) was added. From this it would seem that the only part of the spine which can be considered to be enamel is the small apex which is dissolved away by the acid, or else that the basal cells of the epidermis first secrete a substance which is

largely animal (not mineral) matter, a substance which closely resembles the matrix of the scale itself. But I know of no case of true enamel in which the secretion is of such a mixed nature.

Whether the bony material of the spine or the enamel tip begins to be formed first I have no means of determining. I believe that the two formations begin nearly simultaneously, although there is some reason for thinking that the enamel is not secreted until a part of the bony spine has been formed, for in a few cases I find peculiar abnormally shaped tips (Plate I. Fig. 6, Plate III. Fig. 18, and Plate IV. Fig. 26) which are more readily explained upon the former assumption. These all occur on individuals raised in aquaria, and I believe them to be due entirely to artificial influences, — perhaps to handling. If the enamel were already present over the tip of the spine, I cannot believe that its point could be so distorted, whereas the matrix of the bony part of the spine is probably somewhat plastic when first secreted. It is also conceivable that, before the commencement of secretion, some distortion of the papilla permanently altered its form and caused the abnormal shape of the spine. This seems to me less probable, however, in view of the particular forms which the points of the spines have taken.

The material of the spine is in lamellæ, though these are not as distinct as in the scales. The insoluble part of the point (Plate II. Fig. 12, *b*) is doubtless made up of the first formed lamellæ of the spine which have separated from the rest of the cone on treating with caustic potash. In Figure 25 (Plate IV.) is shown the splitting between lamellæ caused by an oblique cut through the basal part of a spine. No scleroblastic cells, however, are enclosed between the layers, and the material of the spine therefore differs from that of the scale at its base in that particular. But the absence of enclosed cells is not surprising, in view of the thinness of the walls of the spine. In reaction toward acids there is no difference between spine and scale.

The number of spines upon a scale is wholly indefinite, and their arrangement for the most part not subject to any precise law. They are more numerous near the free (i. e. posterior) margins, and here show a tendency toward an arrangement in lines parallel with the edges of the scale (Plate IV. Fig. 31). I have counted over thirty spines on the posterior margins of a scale whose central area was nearly destitute of them. Though some spines are formed near the centre of the scale, by far the greater number arise near the posterior edges. With the growth of the scale, however, the margin advances, leaving them farther and farther from the edge.

The scleroblasts overlying the scale about the bases of the spines do not cease their secretive activity when the spines are completed, but their secretion continues to be employed gradually to thicken the scale by additions to its upper surface. The amount of material so added is very little in the central part of the scale, but toward the margins, where growth is still taking place, and where the greater number of spines are formed, it is considerable (Plate II. Fig. 13). This results in the basal ends of the spines being surrounded and incorporated in the outer layers of the scale (Plate IV. Figs. 24, 25). These outer layers also contain enclosed cells, and are composed of exactly the same material as the layers immediately underlying them.

It is this outer part of the scale which Klaatsch believes to be the enamel layer of Hertwig and other authors, and which he calls *ganoin*. He says (p. 141): "Sie [die Ganoinschicht] entsteht im Anschluss an die Zahnbildung auf der Schuppe; sie ist eine direct Fortsetzung des Zahnbeins der kleinen Schuppenzähne." He also says (p. 132): "Die Substanz der Ganoinschicht stimmt in ihrer homogenen Beschaffenheit mit dem Dentin der Zähnchen überein."

In this I believe that Klaatsch is in error. It is inconceivable to me that any one who had seen ground sections of the ganoin under the microscope could for a moment confound with it the dentine of the spines. Moreover the figure of ganoin given by Klaatsch (Tafel VII. Fig. 6) represents a condition quite different in appearance from that presented by the true ganoin. Furthermore, as shown by the table already given (page 117), I found no trace of the ganoin layer on the scales of a fish 289 mm. long while the fish from which Klaatsch's material came was only 180 mm. long. Reissner ('59, p. 260) says concerning the spines "ihre Insertionsstellen unmittelbar unter dem Schmelz liegen." The presence in this outer layer of enclosed osteoblasts, which are absent from the layer described by Reissner and Hertwig, the fact that it is not destroyed by acid, and its optical properties, all give convincing proof that the material secreted "im Anschluss an die Zahnbildung auf der Schuppe" is not the layer described by Hertwig and others as enamel. If then, as I believe, Klaatsch did not see the layer in question, his claim in regard to its origin can have no weight, and the question of its source remains where Hertwig left it.[1]

[1] It is only fair to state, however, that both the 17.5 cm. and the 19 cm. gar pikes which I studied were killed in acids, so that I have no undecalcified material of the same size as that which Klaatsch studied, for a perfect control of his statement about the ganoin layer.

I have frequently found in sections of scales of different ages, killed by various reagents, a narrow marginal zone appearing somewhat different from the rest of the section (Plate I. Fig. 3, and Plate III. Figs. 17, 20). This often appears strikingly like a different layer of material, and is sharply bounded from the deeper-lying layers. I believe that this appearance is due to the action of reagents used in killing or staining (*in toto*), or both, and not to any natural difference between the parts of the scale. No such difference is found in material killed in alcohol. Klaatsch refrains from stating anything concerning the methods he used or the manner in which his fish had been killed. The impression produced by the study of his paper is that he was misled by some artificial condition such as I have just mentioned and figured.

I have already stated that the spines frequently leave no trace of their existence in the adult scale. To what their disappearance is due I am unable to state positively. Before the outer layer begins to be formed they have almost completely disappeared from all the central part of the scale, but usually a few still remain close to the posterior edges. Hertwig ('79, p. 7, Taf. II. Figg. 1, 2, 3, 10) has described and figured certain little knob-like elevations projecting up into the ganoin layer, and he believes them to be remnants of spines which have been lost. In this conclusion he agrees with that already expressed by Reissner ('59, p. 260). I have carefully looked through series of sections from two different adult "gars" for such structures, but without finding them. Hence it would appear that their occurrence cannot be considered a constant feature. In scales from one young fish 46 cm. long, however, I found some peculiar structures similar to those figured by Hertwig. One of these is shown in Plate II. Figure 14 and is without doubt, as Hertwig maintained, the base of a lost spine. It had been entirely buried in the ganoin. There were also present a number of other much smaller bodies lying between the top of the scale and the overlying tissue in the space from which the ganoin had been dissolved. These were widely scattered, and many were little larger than an odontoblast cell; they were of an ovoidal or spheroidal form, and appear to be the same in composition as the one figured (Plate II. Fig. 14), and I am led to the conclusion that they are also remnants of the bases of lost spines, which were probably in process of absorption when the secretion of the ganoin began and buried them. Hence I believe that the obliteration of spines is in general due to absorption, though it is hardly conceivable that the distal part of the spine dis-

appears in this way. That the disappearance of the spines is due to resorption was suggested by Hertwig ('79, p. 8).

The ganoin layer begins to be formed first over the central area of the scale, and covers all but a very narrow marginal zone, as a regular coating of uniform thickness. At this time the spines have mostly disappeared from all except the posterior margin. The ganoin is separated from the bony part of the scale by a distinct, regular line, and shows markedly different optical properties. It is more highly refractive than the part below, and appears entirely homogeneous except for a very delicate striation parallel to the surface, which probably corresponds to irregularities in the rate of deposition. It cannot be seen in cut sections, since it is entirely destroyed by decalcification, without which section cutting is impossible in scales of this age. In sections prepared by grinding it presents the appearance seen in Plate II. Figure 15. As seen from the surface, too, the appearance is quite unlike that of the bony part of the scale, which is not covered by it (Plate IV. Fig. 27). A knowledge of this layer can be obtained only by combining the results of study both of sections from decalcified tissue and of preparations made by grinding undecalcified scales of the same stage of development.

I find the ganoin layer first present in a fish 52 months old (30 cm. long) reared in confinement; it is also present, and a very little thicker, in a fish of the same length from Quincy, Ill. (Plate II. Fig. 15). In the former case the relation of the scale to the epidermis could not be made out, but in the latter all the tissues were well preserved in a perfectly healthy condition, and the epidermis was distinctly separated from the scale by a thin layer of dermal scleroblasts seldom over two or three cells thick (Plate II. Fig. 16, and Plate IV. Fig. 23). The former of the two figures cited shows about an average condition, and the latter a place near the opening of one of the canals which pierce the central part of the scale where the blood-vessels and surrounding tissue make an unusually thick sub-epidermal sheet. Small blood-vessels are abundant in this layer.

On the scales of a young Lepidosteus 44 cm. long, in which the layer of ganoin had a thickness approaching that found in the adult, the sub-epidermal layer still persisted over the scales of both the ventral and the dorsal regions, though in the latter the epidermis showed a perceptible decrease in thickness.

I am therefore led to the conclusion that, as maintained by Klaatsch, the outer scale layer, called enamel by L. Agassiz, Reissner, and Hertwig,

is secreted, not by the epidermis, but by cells of dermal origin. Hence it is not enamel in the modern sense of the term, but may better be known by the name of ganoin, the term introduced by Williamson and recently revived by Klaatsch.

The great difference in physical properties between this ganoin and the underlying layers of the scale, and the striking resemblance which it bears to the enamel of the scales of Selachians and of the teeth of lower vertebrates, have suggested that the secretion of the epidermal cells may have made its way through the very thin layer of dermal tissue separating the epidermis from the scale. If this were so, the thin layer of sub-epidermal tissue with its rich blood supply would have to be regarded merely as a device for providing an adequate supply of nourishment to the epidermis during its work of secretion, — a device not necessary in the case of the selachian spines by reason of the small size of the secreting area, nor in the mammalian tooth, because of the sunken position of the enamel organ in the gum. This theory would also account for the absence of prismatic structure in the layer.

The condition of the cells of the basal layer of the epidermis, however, makes this hypothesis untenable. There is nothing in their form or appearance to give any ground for comparing them with the cells active in secreting the enamel cap upon the points of the spines in Lepidosteus, or with the cells which in the Selachians secrete the enamel which coats the scales. They are not more elongated than in early stages when the scale is just beginning to form; their nuclei are not larger, nor do they show any difference in staining quality; in short, it is impossible to look upon them as an enamel organ. (Compare Figure 10 with Figures 16, 22, and 23.)

We are thus compelled to admit that the dermal scleroblasts give rise to three different products: (1) calcareous scale material with animal matrix and included scleroblasts; (2) ganoin; and (3) a membrane which Hertwig has called enamel membrane, but which may better be known henceforth as ganoin membrane.

This membrane is clearly visible in all sections of tissue from which the ganoin has been dissolved away (Plate II. Fig. 16). It is a structure which is entirely distinct from the basement membrane with which it was confounded by Hertwig, and in sections appears thicker and more prominent than the basement membrane (Figs. 16, 22, and 23).

It appears that we have to do here not with a differentiation of the cells of one layer, but rather with a modification of the function of the same cells at different periods in their history. The only case at all

comparable to it with which I am acquainted is that of cartilage cells, which in the formation of endochondral bone become transformed into osteoblasts; i. e. the character of the secretion of the same cells is different in the different periods of their activity, and hence to that extent the two cases are similar.

In young scales in which the ganoin layer is still thin it forms an even coat, and the striation visible in it is parallel to the surface. In sections of older scales there are, near the edges, a series of notches in the lower surface of the ganoin which conform to inequalities of the upper surface of the underlying bony layers (Plate II. Fig. 16). Similar conditions have already been described and figured by Williamson and others. Figures 15 and 16 (Plate II.) show that each notch marks the point which was once the edge of the ganoin layer, and that the formation of ganoin on one side of this point (right, Fig. 16) and of bony material on the other must have gone on for some time without any lateral extension of the ganoin taking place. It is also evident that extensions of this layer equivalent in amount to the distance between successive notches must have taken place periodically, not by continuous growth. The cause of such periodicity I have no means for determining.

The fine striations (lamellation) in the ganoin which have already been mentioned have directions in this part of the layer slightly different from those in the region farther from the margin of the scale. Instead of being parallel with the upper surface, they are conformable to the earlier surfaces of the layer, and so have a dip downward toward the underlying bony material as they approach the edge of the scale. They also gradually diminish in thickness toward the central area of the scale, showing that the process of secretion went on less rapidly there than it did nearer the margin of the scale.

The "tubes lepidines" of Williamson are clearly visible in ground sections, though not present in cut sections of decalcified scales. They are due to the presence of uncalcified connective tissue fibres, as has been stated by Klaatsch. These fibres in drying shrink, and so leave minute spaces about them which the balsam does not enter (*tbl. lpd.*, Plate II. Fig. 15, and Plate III. Fig. 21). The course of these "tubes" is very characteristic, and is shown in Figure 15. They are absent in the part of the scale immediately beneath the ganoin layer; they begin in that part which was first formed, and from here they radiate, — the directions being downward in the middle of the scale and diagonally downward and outward near either end of the section.

Klaatsch says concerning them (p. 129): "Untersucht man eine Schuppe des jungen Lepidosteus in getrocknetem Zustande, nach Isolation mit verdünnter Kalilauge, so findet man in ihr sehr zahlreiche zu ihrer Oberfläche parallel verlaufende Röhrchen. Dasselbe gilt von den senkrecht aufsteigenden Faserbündeln. Die Röhrchen, welche sie in getrochnetem Zustande hinterlassen, sind von Williamson bei der erwachsenen Schuppe als 'tubes lepidines' bezeichnet worden."

As may be seen in Figure 15 (Plate II.), the greater number of these "tubes" have an oblique direction; none are exactly parallel to the surface, though the ones near the ends of the section are nearly so, and only a small part are vertical. Thus it is evident that their courses are not the same as those of the fibres of dermis which has not undergone calcification, neither do they agree with Klaatsch's statement concerning them. It is also noticeable that they do not have the same direction as the dentinal tubules among which they lie, but that the two often cross at considerable angles. Klaatsch does not account for this, neither am I confident that I can explain the causes of the differences in direction to which I have called attention; but it would seem to be due to the odontoblast cells — in common with a part of the other scleroblasts — migrating before the advancing line of calcification in a direction perpendicular to the surface of the scale adjacent to them, such migration being however independent of the course of the fibres among which they lie.

I find that the small scales from the under side of the lower jaw agree with the description and figures of Hertwig ('79, pp. 2, 3, Taf. I. Figg. 1–5). They closely resemble the larger scales in all essential respects, differing from them chiefly in size and in having the form unmodified by the proximity of adjacent scales. They are composed of a basal bony plate, which is not destroyed by acid, of which the central part is covered by a layer of ganoin, soluble in acid, about which there remains a narrow marginal area not covered by the ganoin, but bearing one or a few spines. The number of the spines, upon which Hertwig laid emphasis, is, however, as has been stated concerning the larger scales, entirely indefinite, and can be of no morphological importance. The scales described by Hertwig as having one spine owe this condition doubtless to the others having been lost, not to the scale having been developed as the basal plate of that single spine, as is the case in the placoid scale. Such scales cannot therefore be considered as the complete homologues of the placoid scales of Selachians.

Mark ('90, p. 11) has described the act of swallowing in the young

gar-pike; this process gives a satisfactory explanation for the feebly developed condition of the scales upon the under side of the lower jaw. He observed that in the act of deglutition the floor of the mouth became very much distended, so much so as to lead him to compare it to the pouch of a feeding pelican. The frequent distention to which this part of the skin is subjected by the greedy habits of the young fish furnishes a sufficient reason why continuous plates of hard bony material are not formed in this part of the dermis. The small size of the scales described by Hertwig ('79, p. 9) as lying at the bases of the fins is doubtless to be explained in a similar manner. Instead of being atavistic conditions, as maintained by him, they would appear to be due entirely to the action of purely mechanical influences.

I have already spoken of the canals which pierce the central part of the scale, and which have been called Haversian canals by Hertwig and Klaatsch. Their usual course is from below directly through the scale to the upper surface, where the vessels which traverse them spread out in all directions through the sub-epidermal layer. There are sometimes one or two vessels of considerable size which at the upper surface break up into small branches, but quite as often the canal is filled by a large number of minute vessels apparently distinct from one another. The course of these canals is not, however, by any means constant. I have found that sometimes, instead of running directly through, they extend for some distance inside the scale parallel with the surface. Indeed, in the scales of one fish (287 mm. long) the rule seemed to be for quite a number of canals to run horizontally through the scales for considerable distances. This condition seems to me to give an additional reason for regarding these canals as Haversian, or perhaps better — since the osteoblasts are not arranged in concentric lamellæ about them — as Volkmann's canals. Figures 28 and 29 (Plate IV.) are from sections of such scales. In the former figure the canal extends the greater part of the length of the scale and opens to the surface at five points, near those marked *for.*, as can be seen in other sections not figured.

The surface contour shows some quite marked peculiarities in several instances. Figure 30 (Plate IV.) represents a portion of a scale from the same fish as the one last mentioned (287 mm. long). The upper surface bears numerous rounded elevations or hillocks, upon which for the most part the spines are borne. The variations in shape and height are indicated in the figure. Frequently the canals pierce the scale just beneath these elevations and open to the upper surface at one side, as indicated by dotted lines. These slightly abnormal conditions seem to

me to show that not only in histological structure, but also in surface contour and in the degree to which Haversian (or Volkmann's) canals are developed, Lepidosteus scales stand somewhat more nearly related to those of Polypterus than has been held to be the case.

The relation of the Ganoid scale as seen in Lepidosteus to those of other groups of fishes remains to be considered. If my conclusions with regard to this case be true, the idea that any Ganoids have enamel-covered scales will have to be discarded, for Polypterus scales are so nearly like those of Lepidosteus as to make a difference of origin extremely improbable, and no other fishes of this group have scales so closely resembling enamel in physical characters. What relation do the scales of Lepidosteus bear to those of Selachians? In the scales of these two forms there is much that is unlike. In the former the basal plate begins to be formed first, in the latter the spine is the part first to appear; in the former the spines are many upon each scale, and they are small and transient, in the latter there is only one to a scale and they are large and persistent. In the former the scale plate contains osteoblasts, Haversian canals, dentinal tubules, and three crossing systems of incorporated fibres; in the latter only dentinal tubules (not in all respects homologous with those of Lepidosteus) and in most cases a few ends of the vertical set of fibres, though in the more highly developed cases three sets of fibres are found.

There is however one respect in which the two agree quite closely. The spines are in all essential characteristics alike. Both have the tip covered by enamel secreted by the basal epidermis cells; both have the main part composed of calcareous secretion (dentine) of dermal cells lying within and occupying a central cavity. Both have a system of dendritic tubules extending from the cavity into the region of the tip, and both arise by the calcification of the outside of a dermal papilla. These must, then, be taken as the fundamentally homologous parts, and must serve as the basis for comparison.

In the Selachians the simple spine has remained as the typical structure, and only in the more highly developed cases (Mustelus lævis) has the basal plate been developed to the extent of incorporating in itself the fibrous dermis.

In the Ganoid scale two changes have taken place in the passage from the condition in Selachians: —

1. The basal plate has increased in size and in complexity of organization until it has become the essential structure; not only has it incorporated in itself the dermal fibres, but with them it has also taken

in the scleroblastic dermal cells to become osteoblasts, and in connection with this process it has developed a system of tubules for supplying them with nourishment. Moreover, instead of being formed simply as a continuation of the process by which the spine is produced, it has come to develop independently of the spine, for it is only in a late stage of its growth that the two become united. Thus the Ganoid scale plate seems to have arisen from the placoid basal plate by increase in size and with important modifications.

2. The spine, on the other hand, has become reduced in size and in complexity of structure, and is in Ganoids (Lepidosteus) only a rudimentary organ arising late and disappearing early, as is frequently the case with degenerate structures, the "wisdom teeth" of man being a familiar illustration of this.

Hertwig's view is that the scales of Lepidosteus have arisen by the fusion of numerous smaller basal plates of scales of the Selachian (placoid) type. Each spine upon a scale of Lepidosteus therefore represents a primitive placoid scale, and the whole Ganoid basal plate has arisen by the fusion of as many simple scales as the total number of spines formed upon its surface. Klaatsch objects to this interpretation, since the number of spines is so large and wholly indefinite, and because the spines lack such an orderly arrangement as that which the scales have in selachians.

My own view in regard to this matter is essentially the same as that expressed by the latter author. Though the Ganoid scale must be regarded as a more highly developed basal plate than that found in the Selachians, its origin is not due to the fusion of many small ones, but rather to the calcification which in Selachians originated in connection with the formation of placoid spines, having become in Lepidosteus an independent process no longer dependent upon the impulse given by the growth of the spine. The hereditary tendency toward the growth and calcification of papillæ still shows itself, however, in the formation of the small spines, though these are retarded in time and but feebly developed.

As long as each spine had a basal plate, as in Selachians, the spatial requirement of this plate exercised a controlling influence upon the number and the arrangement of the scales (= spines). When now, as in Lepidosteus, the spines have come to arise independently of the underlying plate, such restraint is removed, and we consequently find an increase in the number of the spines and a lack of regularity in their arrangement.

Upon the development of the scales of Teleosts I have made no observations, but employ for comparison with the process in Lepidosteus the accounts given by Klaatsch and Hofer.

In the earliest stages of development a similar modification of the dermis takes place in both cases, giving rise to local thickenings of this layer within which the scale begins to be formed as previously described. These I hold to be homologous structures, but not the homologues of the dermal spine papillæ of Selachians.

The resulting bony plates formed in the two cases are homologous but that of Lepidosteus attains to a much higher degree of development than the one formed in Teleosts. The part to be formed first in the Teleost scale is, as in Lepidosteus, the outer more homogeneous part, but in many cases it differs from the corresponding part of the scale of Lepidosteus in the absence of enclosed osteoblasts. That these are present in some species and absent in others which are very near relatives shows that this difference cannot be of any great morphological importance. Whether they have been secondarily acquired in one case or secondarily lost in the other need not concern us here. Their absence in some cases cannot prevent the layer being considered the homologue of the corresponding layer in Lepidosteus.

The deeper fibrous part of the Teleost scale is the later formation, and in this respect, as well as in general structure and method of development, agrees with the deeper part of the scale of Lepidosteus.

The outer layer of the Lepidosteus scale, the ganoin, which is the part latest formed, is absent in the scales of Teleosts. It is a layer which has been developed within the order of Ganoids, and is not found in any other group of vertebrates.

Throughout the series of scale structures beginning with the Selachian type there has been a constant tendency toward reduction of superficial parts (spines) and increase of the deeper parts which are independent of the epidermis. In Selachians the process of scale formation begins at the surface of the dermis just beneath the basement membrane. In Ganoids there is the same process repeated at the base of the epidermis, but in a much less vigorous manner, while the principal activity is deeper-seated, in the midst of the dermis. In the higher Teleosts the whole scale growth is within the dermis, and the more superficial process is entirely lost.

Thus I believe that the basal plate of the scale of Lepidosteus and the Teleost scale have both been derived from the basal plate of the placoid scale, and have for the most part been modified along the same lines.

That the general course has been the same in both cases is shown by the fact that a broad flat bony plate composed of two layers, an outer more homogeneous and a deeper fibrous one, has resulted in both cases, that these have developed ontogenetically in a very similar manner, and have come to overlap one another in similar diagonal rows. This has, in both cases, involved the reduction of the spines, which in some of the lower Teleosts (e. g. Siluroids) and in Lepidosteus are present in a degenerate condition, but are absent in the greater part of the Teleosts. That in some of the lower Teleosts (e. g. Hypostoma) they do not fuse with the basal plate, but are joined to it by connective-tissue fibres only, may be considered an evidence that degeneration has here gone a step farther than in Lepidosteus.

Klaatsch's idea that the upper layer (Hyalodentin) of the Teleost scale is homologous with the ganoin layer cannot be true, for the two develop quite differently and their physical and chemical properties are very unlike. If, as I believe, Klaatsch did not see the true ganoin in Lepidosteus, but mistook for it the outer part of the bony scale below, his conclusion in regard to the homology of this layer is in perfect accord with that which I have expressed.

If my conclusions concerning the origin and nature of the outer layer (ganoin) of the scales of Lepidosteus is correct, it will follow that no very close and direct relationship can exist between these scales and teeth. Their only relationship is such as arises from the fact that they are both derived from an ancestral condition similar to that found in the scales of Selachians. This primitive condition has been modified by changes leading in opposite directions. In the mouth, the spines have been developed to form the teeth; on the surface of the body, the basal plate has given rise to the scales. Thus each represents at present only a highly modified part of the early ancestral prototype.

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EXPLANATION OF PLATES.

All figures were drawn with the aid of an Abbé camera lucida, from specimens of Lepidosteus osseus, L.

ABBREVIATIONS.

ba. spi.	Base of spine.	*mb. gan.*	Ganoin membrane.
can	Canal.	*nl.*	Nucleus.
chr'ph.	Chromatophore.	*od'bl.*	Odontoblast.
drm f'br.	Fibrous portion of dermis.	*pap. spi.*	Spine papilla.
drm. spng.	Spongy " "	*pig.*	Pigment.
fac.	Surface.	*sc.*	Scale.
fac. e'drm.	Surface of ectoderm.	*scl'bl.*	Scleroblast.
for.	Foramen.	*spi.*	Spine.
gan.	Ganoin.	*tbl. de.*	Dentinal tubule.
gln.[1]	Gland, first kind.	*tbl. lpd.*	" Lepidine tubule."
gln.[2]	Gland, second kind.	*vs. sng.*	Blood-vessel.
mb. ba.	Basement membrane.		

PLATE I.

Fig. 1 Longitudinal section of skin of young gar-pike, 145 mm. long × 140

" 2. Mucin gland cells of ectoderm; *a–d*, stained with Kleinenberg's hæmatoxylin: *e*, stained with Boehmer's alum hæmatoxylin, *a–d* represent successively younger stages. × 500.

" 3. Longitudinal section through posterior end of very young scale from fish 150 mm. long. × 262.

" 4 Optical section of ectoderm, parallel with surface; from tissue stripped off from surface of scales of fish 300 mm. long, after decalcifying the chromatophores lie at a deeper level than the gland spaces, and therefore appear at different focus × 110.

" 5 Section from fish 150 mm. long, showing two stages in the formation of spine papillæ; the section is not quite parallel to axis of larger papilla. × 370.

" 6. A part of the section next to that represented in Figure 5, showing summit of larger spine papilla and its peculiar shaped secreted tip *x* is line in which the farther plane of the section cuts the basement membrane. × 370.

" 7. A longitudinal section through a spine to show the canal connecting its central cavity with the exterior. × 100.

" 8. Odontoblast with its process extending into dentinal tubule From lower surface of scale of fish 400 mm. long. × 500.

" 9. Another odontoblast, having two nuclei Conditions as in Figure 8.

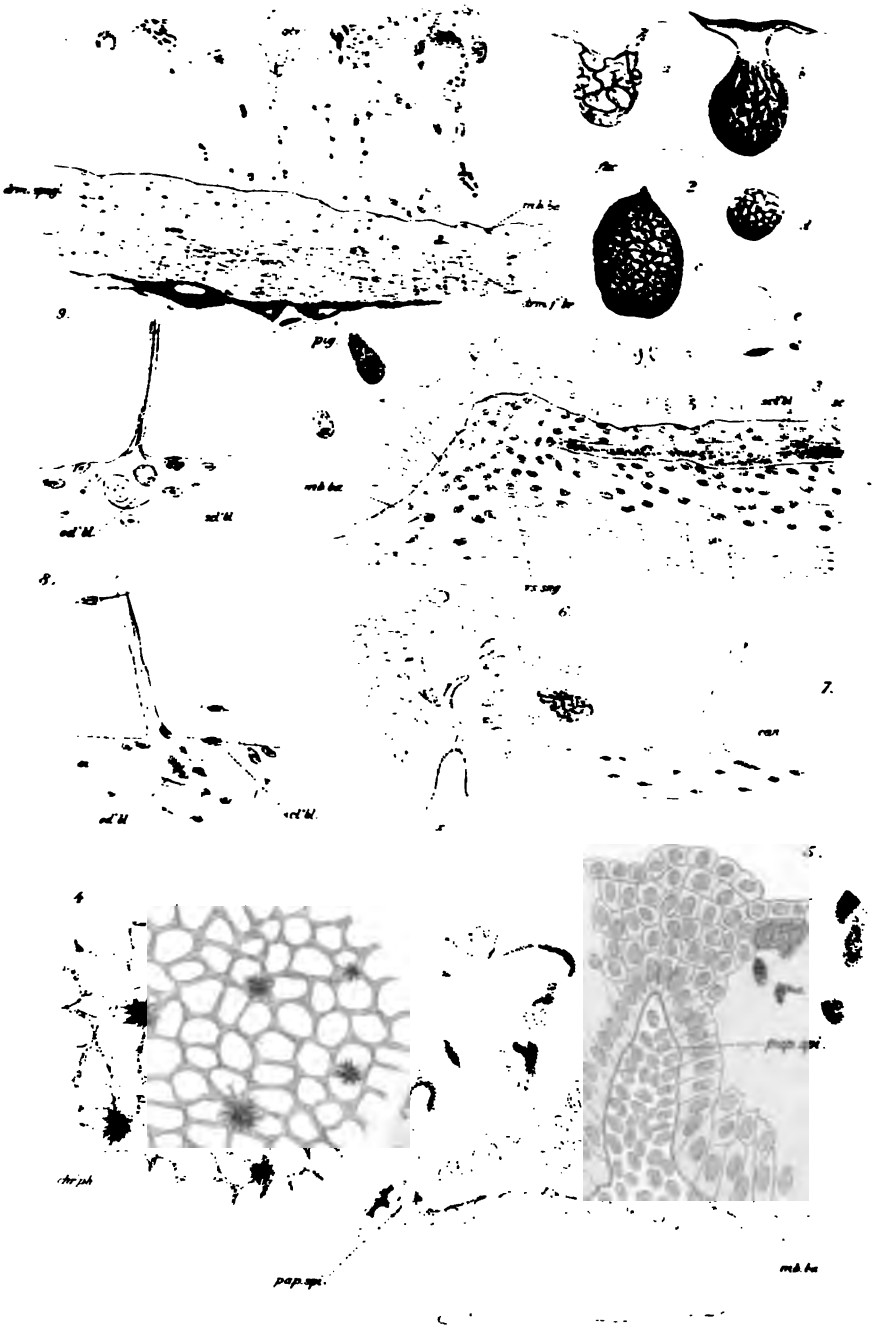
2.
9.
8.
6.
7.
4.
5.
pig.
mb.bc
pap.sp.

PLATE II.

Fig. 10. Section through the axis of a spine papilla in which secretion has begun. From fish 150 mm. long. × 387.

" 11. Optical section of spine broken off from scale of a young Lepidosteus 300 mm. long. × 387.

" 12. Tip of spine loosened by use of caustic potash, *a*, before treating with hydrochloric acid, *b*, after applying acid. × 137.

" 13. Section through posterior edge of a scale from a fish 300 mm. long (52 months old), showing portions of imbedded bases of four spines. × 280.

" 14. Base of a lost (resorbed?) spine, which had been surrounded by ganoin before the latter was destroyed by decalcification. From fish 460 mm. long. × 198.

" 15. Section (prepared by grinding) through scale of fish 300 mm. long, from S. P. Bartlett. × 31.

" 16. Section through posterior margin of decalcified scale from fish 300 mm. long. × 198.


16.
gan.
mb.ba.
mb.gan.
11.
tbl.de.
tbl.de.
tbl.lpd.
10.
15.
tbl.lpd.
14.
ba.spi
tbl.de
spi.
tbl.de.
12.
a.
b.
gan.
spi.
13.

PLATE III.

Fig. 17. Section through axis of a spine showing the difference in appearance between the superficial bony layers of the scale and those lying deeper. From fish 190 mm. long. × 370.

" 18. An abnormally shaped spine tip. × 370

" 19. Fibrillar appearance of the under surface of a scale from a fish 287 mm. long, after treatment with caustic potash. × 275.

" 20. Section through anterior edge of a scale from a fish 190 mm. long; showing fibres of connective tissue in the scale. × 275.

" 21. Portion of ground section of scale of fish 300 mm. long. × 152.

" 22. Portion of section of scale and overlying tissue from a fish 460 mm long. × 198. In a ground section of an immediately adjacent scale the ganoin layer on the corresponding part was 12–15 μ thick. Both in this and the succeeding figure (Plate IV. Fig. 23) an odontoblast is shown lying upon the upper surface of the scale and sending its process down through the ganoin layer in a dentinal tubule.

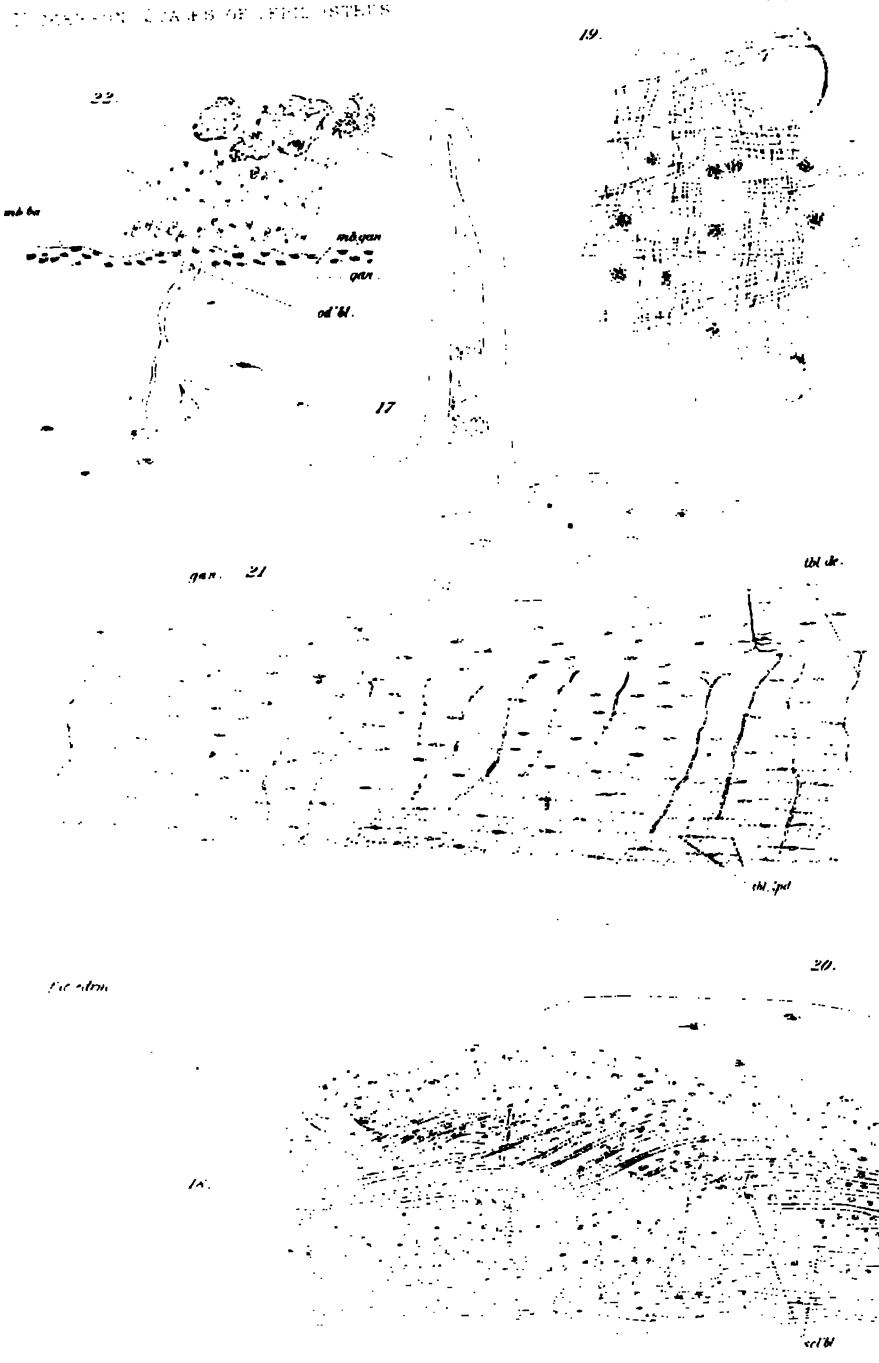
22.
mb. ba
mb. gan
gan.
ed. bl.
17
19.
gan.
21
tbl. de.
tbl. pd
20.
18.
ed. bl

PLATE IV.

Fig. 23. Portion of section of scale and overlying tissue from a fish 460 mm long. × 362. See description of Figure 22, Plate III.

" 24. Base of spine beginning to be imbedded in the outer layers of the scale. From fish 180 mm. long. × 370.

" 25. An oblique section through the base of a spine partly imbedded in the scale. From a fish 300 mm. long. × 387.

" 26. Section through a spine having an abnormally shaped tip. × 105.

" 27. Surface view of posterior extremity of a scale freed from soft tissues by treatment with caustic potash, showing loosened cap on point of spine. × 75.

" 28. Longitudinal section through a scale of a fish 180 mm. long. × 44

" 29. Longitudinal section through a scale of a fish 287 mm. long. × 25

" 30. A representation of a portion of the surface of a scale of a fish 287 mm long. The dotted lines show the positions of Haversian (or Volkmann's) canals beneath the surface. × 31.

" 31 Outlines of several scales of a fish 300 mm. long. The dots indicate the positions of the spines on four scales. × 6½.

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STUDIES IN MORPHOGENESIS.

I. ON THE DEVELOPMENT OF THE CERATA IN ÆOLIS.

BY C. B. DAVENPORT.

WITH TWO PLATES.

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No. 6. — *Studies in Morphogenesis.* — I. *On the Development of the Cerata in Æolis.* By C. B. DAVENPORT.[1]

WHILE at Mr. Agassiz's Newport Laboratory last summer, I collected, early in August, some specimens of Æolis[2] which occurred abundantly on the Hydroids. The individuals varied greatly in size, and, since Nudibranch eggs had been abundant on the same Hydroids earlier in the season, I regarded most of them as immature.

I was particularly struck by the regularity with which the cerata, or dorsal papillæ, were distributed over the surface of the body, and the constancy in position of young cerata in relation to the older ones.

Figures 1 and 2 are drawings of two individuals showing the arrangement of the cerata. They are placed in transverse rows, which are not equidistant, however, but grouped in twos or threes. In each transverse row the largest ceras lies dorsalmost, the smaller more ventral, the youngest of all being often indicated by only a slight protuberance at the base of and ventral to the next older. The regularity of the process of budding of new cerata induced me to make sections to determine its details.

The cerata of Æolis contain, as is well known, processes of the alimentary tract, — the so called hepatic cœca (Plate II. Fig. 12). They are covered externally by the ectodermal epithelium. Between ectoderm and hepatic cœcum are mesodermal cells, which lie (1) in a thin layer at the inner surface of the ectoderm, (2) in a thin layer over the cœcum, and (3) between these two layers, surrounding blood spaces or loosely distributed.

The cœcum of each ceras connects at the base with a lateral diverticulum of the alimentary tract, — gastric diverticulum, — with which also the cœca of all of the other cerata of the same transverse row unite (Plate I. Fig. 3, *ga. dv.*). There are as many of these gastric diverticula as there are transverse rows of cerata (Fig. 4, *ga. dv.*).

[1] Contributions from the Zoölogical Laboratory of the Museum of Comparative Zoölogy, under the direction of E. L. Mark, No. XXXVII.

[2] Owing to the immaturity of the individuals, I was unable to determine the species accurately. Figures 1 and 2, however, show the external form of the species (one or two) employed.

Distal to the cœcum, at the apex of the ceras, lies a sac which in the adult opens to the exterior and is connected at its proximal end with the cœcum in such a manner that the walls of the two organs are continuous, and their cavities confluent through a communicating canal. The existence of this communicating canal, although in past times called in doubt, has recently been correctly reaffirmed by Herdman ('90, p. 52). The walls of the sac are composed of almost completely vacuolated cells, which contain nettling organs or nematocysts. Since the cells of such sacs contain nematocysts, the sacs are called nematophores or cnidophores. Cnidophores are characteristic of the Æolidæ. Figure 13 represents a cross section through a cnidophore, showing the vacuolated cells and the nematocysts therein (*nt'cy.*).

The first indication of the formation of a new ceras is a thickening of the mesenchyme at the base of a young ceras and upon its ventral aspect (Plate I. Fig. 5, *ms'chy.'*). At a slightly later stage (Fig. 6) the mesenchyme has become greatly thickened, and a protuberance of the ectoderm has occurred. Karyokinetic figures indicate that the mesenchymatous mass is growing by cell proliferation. The growing mesenchymatous cells, as well as the adjacent cells of the gastric diverticulum, stain more deeply than those of other regions.

At a slightly later stage (Fig. 7, III.) the wall of the gastric diverticulum (*ga. dv.*) has begun to protrude into the thickened mesenchyme, and the ectoderm is sharply evaginated. Still later (Fig. 8, IV.) these features become more pronounced. The mesenchymatous cells become arranged into three or four layers, of which one is closely applied to the ectoderm, and another to the hepatic cœcum.

It is important to note, (1) that the ectoderm of the new ceras lies, at at an early stage, in the angle made by the body wall with the ventral wall of the next older ceras; (2) that the mesenchyme is directly continuous with that of the ceras, and is in fact transitional from the mesoderm of the trunk to that of the ceras; and (3) that the budding entoderm lies at the distal extremity of the gastric diverticulum, that is to say, at the angle made by the gastric diverticulum, and the last ceras arisen therefrom (Fig. 3, *cer.* 3). The mother cells of each of the three layers of the incipient ceras thus lie in the outer margin of the region whence the corresponding layer of the last formed ceras has arisen. With the development of the ceras it gradually becomes farther removed from the next older one (Fig. 3).

The next stage figured (Plate II. Fig. 9) shows a ceras whose length is slightly greater than its diameter at the base. The mesoderm is

greatly flattened, and the entodermic wall of the cœcum is composed of cuboidal deeply stainable cells. At a stage at which the length of the ceras is less than twice its greatest diameter (Fig. 10), a circular fold occurs in the distal third of the cœcum, constricting the lumen. The cells of the distal compartment stain deeply, like those of the hepatic cœcum of the preceding stage. They do not at all resemble the unstained cells of the ectoderm.

At a stage only very slightly older than the preceding (Fig. 11), one finds the cells of the distal sac partly vacuolated and containing nematocysts. This distal sac can be traced forward into the oldest stages, and it becomes the cnidophore. Its lumen constantly retains its connection with that of the hepatic cœcum through the communicating canal. A communication with the outside world at the apex of the ceras is established only at a later stage by a close approximation of the cnidophore to the apex of the ceras and a disintegration of the apical ectodermal cells.

Herdman asserts in two or three places ('90, p. 52, and Herdman and Clubb, '89, p. 233, '92, p. 552), that the cnidophores arise by an invagination of the ectoderm on the apex of the ceras; but although in his last paper he says he has "shown" it in the earlier ones, I fail to find that he has offered the slightest evidence for his statement. It seemed indeed *a priori* more probable — from what we know of the origin of protective organs, and especially of the origin of nematocysts in the Cnidaria — that the cells of the cnidophore had an ectodermal origin. But they have not. This is the conclusion to which I am forced by the following considerations. (1.) The development just outlined, which has been traced in a series so complete as to leave little chance for misinterpretation. (2.) The absence of an external opening until quite a late stage. Since the axis of the cnidophore does not in later stages coincide with that of the ceras, and since it is not easy to obtain sections which pass through the entire axis of the ceras, especial care must be exercised in determining the absence or presence of an apical opening. Figure 12 is a strictly axial section. The apical ectodermal cell shows signs of degeneration, and its outer surface is sunken in. (3.) The presence of nematocysts in those cells also which lie in the hepatic cœcum *proximal* to the constriction, and for which no one has maintained a derivation from an invagination of the apical ectoderm.

The cells of the hepatic cœcum, especially at a late stage, show large numbers of nematocysts of the two kinds mentioned by Herdman ('90). Cf. Figures 14 and 15. That these nematocysts have been developed

in situ, and have not migrated from the cnidophore through the communicating canal and become incorporated into the "hepatic" cells, is indicated by the fact that they are found in different stages of development (Fig. 14, *nt'cy.'*). One finds first of all small ovoid areas, which stain deeply; later, one finds an elongated deeply staining central streak, while the rest of the vesicle remains colorless. This central streak is the proximal part of the thread. In some cases I have seen in the "hepatic" cells the larger kind of nematocyst mentioned by Alder and Hancock ('55, Expl. Fam. 3, Plates 7 and 8, Fig. 16); in fact, they seem to occur quite as abundantly here as in the cnidophore.

Comparing the origin of nematocysts in the Æolidæ and Hydra, — for a knowledge of which in the latter group we are indebted among others to K. C. Schneider ('90, pp. 332, 345), — the most striking difference is that the nettle capsules in Hydra arise in the ectoderm only (so it is maintained), and that those which do occur in the entoderm have not been formed there, but have been devoured. In Æolis, similar capsules arise in diverticula of the alimentary tract, and therefore from entoderm. Secondly, the nettling capsules of Hydra are formed in indifferent cells lying at the base of the ectoderm; in Æolis they are produced in the large "hepatic" cells. Finally, in Hydra only one nematocyst is formed in a single cell, and this comes to occupy nearly the whole of it; in Æolis several nematocysts (Figs. 13, 14) are produced in a single cell.

This comparison raises the question whether the so called hepatic cæcum is properly named, — whether its cells have either the function of storing up reserve stuff or of secreting digestive fluids. To this question I can give no final answer, but it is worthy of note that the "hepatic" cells of Æolis do contain numerous small granules which stain deeply in hæmatoxylin. This is true even for the cells which produce nematocysts (Figs. 14, 15). A comparison with sections of the hepatic cæca of Doto coronata treated in the same way shows, however, that the "hepatic" cells of Æolis are smaller and contain smaller granules than do those of Doto, in which genus, of course, no nettling organs are formed. From their smaller size, and the smaller size of the contained granules (whether these are stored food stuff or katabolic product), I am inclined to regard the hepatic function of the cells forming the wall of the cæcum of Æolis as less important than in Doto.

The sum total of the nematocysts in the hepatic cæcum of any cerus is much greater than in the cnidophore. On physiological grounds the latter term is in Æolis applicable to the entire cæcum, and not merely to its distal part.

After having found that the cerata arose in close connection with preceding ones of the same transverse rows, and therefore ultimately in close connection with the first or dorsalmost ceras of each row, it seemed desirable to determine the origin of the dorsalmost longitudinal series of cerata, and of the origin of new transverse rows. Sagittal, or slightly inclined longitudinal, and also frontal sections of young specimens gave the desired information. Figure 16 represents a longitudinal section which is not strictly sagittal, the upper edge of the section plane having been tilted about 30° towards the right so as to pass at the same time through the alimentary tract and the dorsal series of cerata, — the only series as yet developed on that side. From the drawing it is clear that the alimentary tract sends off diverticula, which pass directly into the first cerata of each transverse row. Behind the most posterior ceras the mesenchyme is thickened over the alimentary tract, which runs to the posterior end of the body. In a section a little removed from this (Fig. 17, II.), one sees the beginning of another papilla behind number III. of the series represented, — the foundation of another transverse row. The ectoderm has already begun to fold upwards, and the alimentary tract sends out a prominent pocket.

Of very great importance is the fact that just behind the Anlage of the ceras the testis is arising, so that the mesenchyme which seems to take the initiative in the formation of the ceras gives rise also to the sexual cells. Moreover, the two cell masses arise close together, and indeed in a definite relation to each other. As is clear from an inspection of Figure 16, the sexual glands — ovary and testis — lie between the transverse planes occupied by the cerata, and in each mass the ovary lies in front of the testis, so that successive transverse sections cut from the head backwards pass in order through a transverse row of cerata, through an ovarian mass, and through a testicular mass. This succession is, however, not that in which the Anlagen of the three organs have been established out of the mesenchyme of the tail end; for, as Figure 17 indicates, new sexual cells arise before the ceras which lies in front of them begins to appear.

The oblique (nearly frontal) section, Figure 18, shows the same relation of the sexual glands and the cerata. A reconstruction of the series shows that diverticula arise from the parts of the alimentary tract indicated by the designations *cer.* I., II., III., and IV. These diverticula correspond in position to transverse rows of cerata. The same reconstruction shows that between these diverticula ovary and testis follow in the way just described. At the extreme tail end the section passes obliquely through

the glands of the foot, then through the mass of indifferent mesenchyme which lies under the dorsal ectoderm at ✱. Just in front (IV. ♂) sexual cells are being cut off from the mesenchyme as a paired mass whose two lobes are united in the median plane.

I have above assumed, somewhat gratuitously, that the mesenchyme takes the initiative in ceras production. The evidence for this lies in two facts. (1.) The first indication of the formation of the new ceras is seen in the thickening of the mesenchyme at the base of the next older ceras (Fig. 5). It is not until after a solid mass of mesenchymatous cells is produced that the ectoderm begins to evaginate, almost as though pressed outwards (Fig. 6). The alimentary diverticulum is produced still later (Fig. 7). (2.) That the cœcum does not take the initiative is indicated by the fact that I have found young cerata composed only of ectoderm and a thickened mesenchymatous core, the entoderm not having yet penetrated into it.

The capacity possessed by Nudibranchs of regenerating the cerata is well known. I have not experimented with them, and have no sections of stages in the process. The known phenomena of regeneration in other cases makes it probable that the capacity for regeneration depends upon the existence of embryonic tissue. We should therefore expect to find thickened, embryonic mesenchyme lying at the base of the dorsal papillæ. As a matter of fact we do find it, as is shown in Figure 16 at the base of cerata II and III. (✱). The mesenchyme at the base and in front of ceras I. was torn away in sectioning; in adjacent sections the basal mesenchyme appears thickened here also.

The foregoing study of the development of the cerata of Æolis points emphatically to one conclusion, namely, the embryonic or growth tissue of Æolis is in its origin identical with that producing sexual cells. Like the latter, it is germ tissue; it differs from the sexual cells chiefly in this, that it gives rise to growths constituting part of the body of the present individual, — growths which are as mortal as any other part of the present individual; whereas the sexual cells play no part in the production of the present individual, but eventually give rise to a new individual and its germ tissue. It differs, secondly, from the sexual cells in this, that it gives rise to one kind of organ only, — the mesenchyme to the mesenchyme of the buds, the entodermal diverticulum to the entoderm of the buds.

The mesenchymatous growth tissue of Æolis resembles the sexual cells, however, in this, that while it goes to produce the mesenchyme of any ceras, *a*, not all of it is used up in forming the mesenchyme of ceras *a*, but some of it remains behind to form a new ceras, *b*, and the Anlagen of other new cerata. Thus, as in any young individual we may distinguish between the differentiated tissue and the germ tissue from which new individuals will arise, so in any ceras we may distinguish between the differentiated tissue and the embryonic tissue from which new cerata will arise.

While, however, the sexual cells have the capacity of reproducing new individuals indefinitely, the mesenchyme at the base of the cerata does, as a matter of fact, produce only a limited number of cerata. Of this limitation there are, however, all degrees. In some cases, as in Doto, only one ceras is produced in a transverse row; in some species of Æolis, on the other hand, young cerata are produced, even in adult individuals, at the ventral end of the long transverse rows, so that here the growth is apparently limited only by the duration of life of the individual. In all cases the limitation in the reproduction of cerata must be considered as resulting, not from the limited capacity of reproduction of the embryonic tissue, but from the needs of the species.

CAMBRIDGE, December 20, 1892.

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PLATE I.

ABBREVIATIONS.

an.	Anus.	*ga.*	Stomach.
can. comm.	Communicating canal.	*ga.'*	Prolongation of stomach backwards.
cer. 1, 2, *etc.*	Cerata of the same transverse series.	*ga dv.*	Gastric diverticulum at base of transverse rows of cerata.
cn'ph.	Cnidophore.	*ms'chy.'*	Mesenchyme of developing ceras.
cæ.	Hepatic cæcum.	*œ.*	Œsophagus.
cæ.'	Forming hepatic cæcum.	*pd.*	Foot
cpl.	Capillary vessel.	*rt.*	Rectum.
ec'drm.	Ectoderm.		
ec'drm.'	Ectoderm of young ceras.		
en'drm.'	Entoderm of young ceras.		

Figs. 1, 2. Two figures of young individuals of Æolis sp., showing arrangement of cerata in transverse rows, which are numbered with Roman numerals. × 5.

" 3. Transverse section of a young Æolis showing the stomach, the gastric diverticulum, and hepatic cæca of a transverse row of cerata. × 45.

" 4. Outline of alimentary tract of Æolis, copied from Alder and Hancock, showing gastric diverticula and points of connection of hepatic cæca.

" 5–8. Four vertical sections through different stages in the development of the cerata.

" 5. First stage in formation of ceras. Mesenchyme thickened at ms'chy. Right side. × 405.

" 6. Second stage in formation of ceras. Mesenchyme thickened still further. Ectoderm beginning to evaginate in the axis. Left side. × 405.

" 7. Third stage in formation of ceras. Gastric diverticulum beginning to out fold to form hepatic cæcum of new ceras. Left side. × 228.

" 8. Fourth stage in formation of ceras. Right side. × 228.

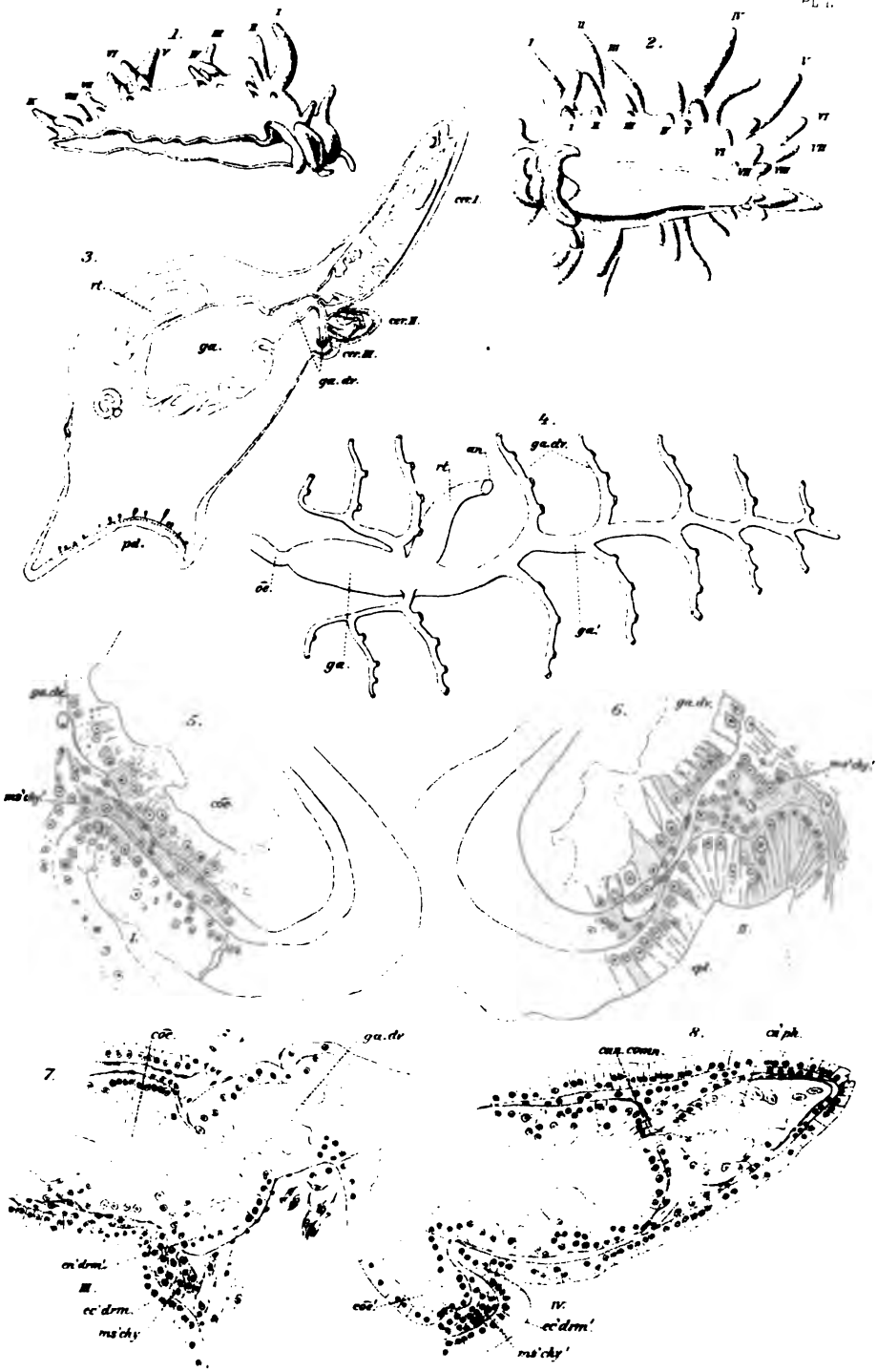
1.
2.
3.
4.
5.
6.
7.
8.
rt.
ga.
ga. dr.
pd.
an.
cœ.
ga.'
ms'chy
ga. dr.
ms'chy'
qd.
cœ.
ga. dr
cœ. comm.
ci'ph.
ci'drm.
III.
cc'drm.
ms'chy
cœ.'
IV.
cc'drm.'
ms'chy'

PLATE II.

ABBREVIATIONS.

can. comm.	Communicating canal.	*ms'drm.'*	Mesoderm lining body wall
cer. I., II., *etc.*	Cerata of I., II., etc. transverse rows.	*ms'drm.''*	Mesoderm lining hepatic cæcum.
cn'ph.	Cnidophore.	*nt'cy.*	Nematocyst, smaller kind
cæ.	Cæcum.	*nt'cy.'*	Developing nematocyst
ec'drm.	Ectoderm.	*nt'cy.''*	Nematocyst, larger kind
gst.	Stomach.	*pd.*	Foot.
gst.'	Posterior prolongation of stomach.	*pe. res*	Penis sac.
gst. dv.	Gastric diverticulum.	*rad.*	Radula.
gl. nid.	Nidamental gland.	*rhn.*	Rhinophore.
gl pd.	Foot gland.	*rt.*	Rectum
gn.	Ganglion (cerebral).	*te*	Testis
mo buc.	Buccal mass.	*ur.*	Ureter
ms'drm.	Mesoderm.	I., II., III., ♀, ♂.	Lobes of ovary and testis.

Figs 9–11. Three stages in the development of the cerata. Vertical sections × 120

" 12. Longitudinal section of ceras just before formation of external opening of cnidophore × 120

" 13. Transverse section of adult cnidophore, showing nematocysts × 405

" 14. Bit of transverse section of hepatic cæcum, showing fully formed and developing nematocysts in hepatic cells × 405.

" 15. Bit of transverse section of hepatic cæcum, showing large nematophore × 405

" 16. Longitudinal section of young Æolis, inclined about 20° from vertical passing through axis of alimentary tract and first ceras of three transverse rows. × 76

" 17. Enlarged view of the posterior of the two regions marked by asterisks in Figure 16, but from a section adjacent to Figure 16, showing parietal mesoderm some of which is about to form that of the youngest transverse row and some to give rise to sexual cells, *te* × 318

" 18. Longitudinal section of young Æolis. Oblique in front, nearly frontal behind. Showing repetition of sexual organs and their relation to transverse rows of cerata × 76


9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
gn. dr.
cor
V.
cdc.
ca'ph.
VI.
II.
VII.
coe.
nt'cy.
ms'drm.
con. comm.
nt'cr.
rad
ma. buc.
gn.
gl. sid
ga.
cor I.
I a
I b
cor II
II a
II b
cor III
III a
III b
ur.
rt.
ms'drm'.
ms'drm''.
ga'
cor IV.
IV a
gl pd.
ga dr.
te.
cor I.
cor II
cor III
rhn
ca'ph
ma buc.
gl pd
pr. vrs
gl. sid.
ga
pd.

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REPORTS ON THE DREDGING OPERATIONS OFF THE WEST COAST OF CENTRAL AMERICA TO THE GALAPAGOS, TO THE WEST COAST OF MEXICO, AND IN THE GULF OF CALIFORNIA, IN CHARGE OF ALEXANDER AGASSIZ, CARRIED ON BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," DURING 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., COMMANDING.

VI.

PRELIMINARY DESCRIPTIONS OF NEW SPECIES OF CRUSTACEA.

BY WALTER FAXON.

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No. 7. — *Reports on the Dredging Operations off the West Coast of Central America to the Galapagos, to the West Coast of Mexico, and in the Gulf of California, in Charge of* ALEXANDER AGASSIZ, *carried on by the U. S. Fish Commission Steamer "Albatross," during* 1891, LIEUT.-COMMANDER Z. L. TANNER, U. S. N., Commanding.

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VI.

Preliminary Descriptions of New Species of Crustacea.[1] By WALTER FAXON.

ORDER PODOPHTHALMIA.

SUBORDER DECAPODA.

Family MAIIDÆ.

Euprognatha granulata, sp. nov.

Carapace coarsely granulate; two erect blunt spines in median line of carapace, one on the gastric, the other on the cardiac area; a transverse row of four or five small tubercles in front of the gastric spine; a spine near the middle of each branchial area, with a smaller lateral spine below and a little in advance of it; the hepatic area bears a short blunt spine on its most prominent part; there are, besides, three or four prominent tubercles on the angle which divides the hepatic and pterygostomian regions. The antennary spine is very long, reaching beyond the rostral horns; the three horns of the rostrum (interantennulary and lateral) are about equal in length; the supra-orbital spines are well developed, and, like the antennary and three rostral spines, are conspicu-

[1] Figures of all the species described in this paper will appear in the final report, whose publication is deferred pending the preparation of the lithographic plates. A record of the stations occupied by the "Albatross" during her cruise of 1891 will be found in Bull. Mus. Comp. Zoöl., Vol. XXIII. No. 1, pp. 4–8.

ously granulated. The post-orbital spines are even more coarsely tuberculated. When viewed from above their margins appear laciniated. Surface of abdomen thickly set with bead-like tubercles; the first segment bears a prominent granulated spine, and there is a rudimentary spine on each of the three following segments. Chela slender, covered with small tubercles; the remaining segments of the cheliped and the ambulatory appendages are furnished with small spines, tubercles, and scattered curled setæ.

Length of carapace, 7 mm.; breadth, 6 mm.

Station 3369. 52 fathoms. 2 females.

Anamathia occidentalis, sp. nov.

Carapace pyriform, furnished with spines and tubercles which are arranged as follows: four on the gastric region (two in the median line, two lateral); the posterior median has the form of a tubercle, from which a low blunt keel runs back to the cardiac region; one on the cardiac region, one (tubercle) on the intestinal region, one on each hepatic region, five on each branchial region. Of the branchial spines the one near the middle projects upward and forward, the longest spine of the carapace, one half as long as the rostral horns. In addition to these spines and tubercles there are four or five small tubercles on the outer border of the pterygostomian region. Rostrum produced into two divergent awl-shaped horns, which are more than one fourth the length of the carapace. Pre-orbital spines acute, post-orbital processes obtuse. Chelipeds twice as long as the carapace, not much more robust than the ambulatory limbs; chela little longer than the merus, the basal part cylindrical, distal part gradually widening to the base of the fingers; fingers smooth, slightly curved, less than one half as long as the basal portion; prehensile edges regularly dentate, closing throughout their length. The merus of all the legs has a small tubercular projection at the distal end above, most prominent on the anterior pair. The carpus of the chelipeds has two low ridges on the outer face. Abdomen seven-jointed.

Length of carapace without the rostral horns, 15 mm.; length of rostral horns, 12 mm.; breadth of carapace, 38 mm.

Station 3404. 385 fathoms. 1 male.

MAIOPSIS, gen. nov.

Carapace subtriangular, as broad as long, spinose; rostrum produced anteriorly into two divergent horns with an accessory spine upon their outer margin, inter-orbital space broad. Eyes small, eyestalks slender, retractile within the orbits. Orbits large, with a forward aspect, incomplete below, the upper margin prominent, with two deep fissures, and supra-ocular spines. Epistome [illegible]. Basal segment of antennæ very broad, with three prominent spines upon its anterior margin. Flagellum of the antennæ widely separated

from the cavity of the orbit by a broad process of the basal segment. Merus of outer maxillipeds notched at the antero-internal angle. Legs of moderate length; carpus of chelipeds elongated, not carinated; chela elongated and slender, fingers canaliculate within, but not spoon-shaped at their tips, their prehensile edges meeting throughout most of their length, not distinctly toothed; ambulatory legs spinose. Abdomen (male) seven-jointed, terminal joint short and broad.

This genus is proposed for the reception of an interesting Maioid dredged in 182 fathoms on the west coast of the Isthmus of Panama. It combines in one form characters of the genera *Maia*, *Cyclomaia*, *Paramithrax* (subg. *Leptomithrax*), and *Schizophrys*. In its general aspect it bears a close resemblance to *Maia*, and the likeness is enhanced by the small eyes and slender eyestalks, the elongated wrist and hand, and the short epistome. It differs from *Maia* in having a much broader carapace, a less deeply cloven rostrum, spinose legs, supra-ocular spines, and trenchantly in the exclusion of the antennal flagellum from the orbit by a process of the basal segment of the antenna. In the latter regard it agrees with the genus *Cyclomaia*, the basal segment of the antenna being very broad, three-spined on its distal border, and giving off a process which separates the flagellum from the orbit by a wide interval; it also agrees with *Cyclomaia* in having a short epistome, a short and broad terminal abdominal segment, and supra-ocular spines. It differs from *Cyclomaia* by having a subtriangular carapace, longer rostral spines, and a less abruptly declivous front. It is like *Paramithrax* and *Schizophrys* in the exclusion of the basal antennal segment from the orbit, but this segment is much broader than in these genera, and three-spined; moreover, *Maiopsis* differs from *Paramithrax* and *Schizophrys* in having a more broadly triangular carapace, supra-ocular spines, slenderer wrist and hand, less deeply cleft rostrum, and spinose ambulatory legs. Like *Schizophrys*, it has an accessory spine on each rostral horn. In the shape of the carapace *Maiopsis* is intermediate between *Maia* and *Cyclomaia*. In the form of the fingers it stands between *Maia* and *Paramithrax* on the one side, and *Schizophrys* and *Cyclomaia* on the other, as the fingers, though canaliculate within, are but slightly excavated at the tips. The synthetic character of the species upon which this genus is based suggests the propriety of ultimately extending the scope of the old genus *Paramithrax* so that it may embrace this form, together with *Cyclomaia* and *Schizophrys*.

Maiopsis panamensis, sp. nov.

Dorsal surface of carapace thickly set with spines of various sizes and scattered hooked setæ. The largest spines are distributed as follows: five on the gastric region, one on the genital, one on the cardiac, four on the intestinal, and about seven on each branchial region. Margin of carapace armed with twelve prominent spines, three of which are on the hepatic region. The sternum is ornamented with small tubercles along each side of the abdomen. The

first abdominal segment is furnished with a bidentate tubercle. Legs covered with numerous spiny tubercles; the meri armed with three or more prominent spines at the distal end. Chela long and slender, the tubercles of the hand smaller than on the other parts of the legs; fingers nearly smooth. A deep pit at base of movable finger.

Length from base of rostrum to posterior margin of carapace, 112 mm.; breadth, 113.5 mm; length of rostrum, 22 mm.; length of rostral horns, 11 mm.; breadth between eyebrows, 38 mm.; length of cheliped, 156 mm.

Station 3355. 182 fathoms. 1 male.

Family PARTHENOPIDÆ.

Lambrus hassleri, sp. nov.

This is the Pacific coast representative of *Lambrus pourtalesii* Stimps. (*L. verrillii* Smith) of the east coast of North America. It differs from the latter species as follows: the carapace is broader in proportion to its length; the branchial regions are more expanded and inflated, the inflation extending farther in toward the cardiac area so as to involve the oblique row of small tubercles; that is to say, this row of tubercles, which in *L. pourtalesii* lies low down in the fossa between the branchial and cardiac regions, is raised up, in *L. hassleri*, on the swell of the branchial region. The spines on the edges of the chelipeds, moreover, are not laciniated to such a degree as in *L. pourtalesii*.

Length of a female specimen, 27 mm.; breadth, including lateral teeth, 38 mm.

Station 3368. 66 fathoms. 1 female.
" 3427. 80 " 1 male, 1 female.

This species was previously obtained during the voyage of the "Hassler" at Magdalena Bay, Lower California, August 14, 1872. The specimens then obtained were apparently picked up dead on the shore.

Family CANCRIDÆ.

Xanthodes sulcatus, sp. nov.

Carapace granulated, granulation heaviest on the lower surface, and near the borders of the upper surface. Deeply impressed grooves separate the gastric from the branchial regions, and the mesogastric from the lateral gastric lobes. The groove which continues in the median line to the front, anteriorly to the mesogastric lobe, is crossed a short distance behind the frontal margin by a transverse groove, which meets on each side another groove running parallel to the upper margin of the orbit. In this way there are marked off a pair of frontal and a pair of orbital areas. The frontal margin is nearly straight,

finely denticulate, and separated from the orbital areolets by a groove. Antero-lateral border of the carapace armed with four spines or teeth, E, N, T, S, of Dana's nomenclature, there being no tooth at the external orbital angle; of these teeth the first is the smallest, the third the largest, and the second and fourth are of about equal size; the margins of all the teeth are denticulate. The chelipeds are short and unsymmetrical; the merus is granulated on its outer face, spinulose on the upper edge, and grooved near the articulation with the carpus. The carpus is granulated on its outer side, and furnished with a median internal tooth. The meri of the ambulatory appendages are spinulose along their upper edges.

Length of carapace, 8 mm.; breadth, 11 mm.

Station 3355.	182 fathoms.	1 male, 1 female.
" 3391.	153 "	1 male, 3 females.

Panopeus latus, sp. nov.

Carapace broad, convex in antero-posterior direction, granulated, especially on the hepatic, branchial, and cardiac regions; areolations well marked and protuberant. Front divided by a small median incision into two slightly convex lobes, whose edges are simple and not produced into teeth at the lateral angles. Antero-lateral margin cut into five teeth; post-orbital tooth small, separated from the second tooth by a shallow granulated sinus; the third tooth is the broadest, and rounded off at the apex; the fourth is the most salient, and acute; the fifth is very small, and acute; all the teeth have crenate or else spinulose margins. The margin of the orbit is minutely crenulate; its upper part is marked by two closed fissures; the external hiatus of the orbit has the form of a triangular notch; the lower margin is produced to form an obtuse tooth at the inner angle. The subhepatic region is granulous, but not provided with a tubercle. The merus of the third pair of maxillipeds is also granulated. The carpus of the chelipeds is rough with small tubercles, grooved along the distal margin of the outer side, and armed internally with a small blunt tooth; the hands are robust, inflated, smooth except near their articulation with the carpus where scattering granules appear; upper and lower margins rounded; fingers long, down-curved, smooth, canaliculate, their cutting edges irregularly armed with small and rather sharp teeth, without any prominent basal tooth; when closed the fingers are separated by a slight gape, and their tips cross one another; the color of the fingers in alcoholic specimens is very light brown. The chelæ of the right and left sides are unequal in size, but similar in shape. The ambulatory appendages are setose, their merus joints furnished with small teeth along their upper edges. The seventh segment of the sternum in the male is entirely concealed by the base of the abdomen. The coxæ of the fifth pair of legs are in contact with the third abdominal segment. The penultimate segment of the abdomen has concave sides, the terminal segment is broad and rounded.

Length of carapace, 6.5 mm.; breadth, 10.25 mm.

Station 3397. 85 fathoms. 1 male.

In this species the carapace is short, the posterior margin wider than usual in the genus. In its general aspect it recalls *P. xanthiformis* A. M. Edw.; the meri of the ambulatory legs are denticulated on their upper margins as in *xanthiformis*, but in *latus* the carapace is much broader and more convex in an antero-posterior sense, the front is less prominent and destitute of lobes at the lateral angles, the carpal tooth is blunt, etc.

Panopeus tanneri, sp. nov.

Carapace moderately convex both lengthwise and transversely, smooth and polished in the central and posterior part, coarsely granular on the anterior gastric and hepatic regions. The gastric and hepatic areas are well marked off by depressions. Front nearly straight, divided by a median triangular fissure, and projecting as a blunt tooth at each lateral angle; a double edge is formed by a groove which runs along the front, the lower edge projecting farther forward than the upper edge; both upper and lower edges are finely granulate. The antero-lateral margins of the carapace are cut into triangular teeth; the first and second of these teeth are small, coalesced, connected by a shallow sinus; the third and fourth are of about an equal size; the fifth is much smaller; all the teeth are granulous on their anterior border, smooth on posterior border; the depressions between the third and fourth and the fourth and fifth teeth are continued in as furrows for some distance on the carapace, finally uniting and meeting the cervical furrow. The upper margin of the orbit forms a tooth at the inner angle above and outside of the external marginal tooth of the front; there is a closed fissure near the middle of the superior orbital border; the external fissure is a triangular notch; a blunt tooth at the inner angle of the lower margin. There is no subhepatic tubercle. A transverse row of tubercles on the front of the eyestalk (when viewed retracted within the orbit) just inside the eye. Chelipeds unsymmetrical; carpus squamose-rugose, with a slight transverse groove, and armed with a prominent but not very sharp internal tooth; propodus robust, superior border rounded and squamose-tuberculate, outer surface smooth, fingers of larger chela gaping, movable finger armed with a blunt tooth at base; fingers of smaller chela slenderer, without prominent teeth; fingers of both hands black, hooked at extremities, tips crossing. Base of abdomen entirely covers the sternal segments; penultimate segment of abdomen short, posterior angles prolonged backward; last segment short, pentagonal. In young specimens the granules of the carpus and propodus are more numerous and sharper pointed.

Length of carapace, 6.25 mm.; breadth, 10 mm.

Station 3405. 53 fathoms. 5 male (3 adult, 2 young).

" 3408. 66 " 1 male.

Family PORTUNIDÆ.

Achelous affinis, sp. nov.

Carapace moderately convex both longitudinally and transversely, the frontal region depressed, horizontal; surface rugose, granular, and pubescent. Front not prominent, composed of four blunt teeth, not counting the internal angle of the orbit; the two teeth near the median line are equilaterally triangular, separated from one another by a triangular notch; the next teeth on the outer side are separated from those within by a shallow sinus, and fall off abruptly on the outer side into a deep notch which separates the front from the inner orbital angle. The two middle teeth of the front are a trifle longer than the lateral teeth. The tooth formed by the projecting inner orbital angle does not attain the level of the frontal teeth; it is double, the orbital margin just outside of it being slightly folded, raised, and projected forward so as to form a secondary tooth similar to that in *A. spinimanus*, but not so well marked. The antero-lateral margin of the carapace is nine-toothed, including the tooth at the outer orbital angle; the posterior tooth is hardly larger than those in front of it; the posterior margin of these teeth is convex. The anterior edge of the merus of the chelipeds is armed with five spines. The carpus has an internal and a smaller external spine. There is a spine on the propodus at the base at the point of articulation with the carpus, and another on the upper margin a little distance back of the articulation with the dactylus. The distal edge of the merus of the fifth pair of legs is spinulose.

Length, 25 mm.; breadth, 39 mm.; length of merus of chelipeds, 24 mm.; length of propodus, including digit, 33 mm.; length of internal carpal spine, measured from distal margin of carpus, 3.3 mm.

Station 3379. 52 fathoms. 5 males, 4 females.
" 3390. 56 " 1 male.

A large number were also taken in the tow-net at the surface at the following stations: Off Mala Point; Hydr. 2627; Nos. 3355, 3371, 3382, 3386, 3398; 50 miles south of Guaymas.

The specimens taken at the surface are small, and much darker in color than those that came up in the trawl, but show no structural differences. I take them to be the same species in the pelagic stage of its existence.

This species is very closely related to *Achelous depressifrons* Stimps., from the Atlantic side of the continent. Compared with *A. depressifrons* it is broader, and the curve formed by the front and the antero-lateral margin of the carapace forms an arc with a longer radius; the lateral lobe of the front is broader; the tooth of the inner orbital angle is double, as above described; the teeth of the antero-lateral margin have broader bases, and the anterior one at the outer orbital angle is not so prominent; the protuberances on the cardiac and branchial areas are less prominent; the internal carpal spine is shorter, and the distal margin of the merus of the fifth pair of legs is denticulate behind the articulation of the carpus.

Family CORYSTIDÆ.

TRACHYCARCINUS, gen. nov.

Carapace pentagonal, moderately convex, lateral margins long, nearly straight toothed. Front narrow, produced, three-toothed. Orbits large, with forward aspect, imperfect, with two hiatuses above, one below, and one at the inner angle; lower wall formed chiefly by the carapace. Anterior margin of buccal cavity not distinctly defined, epistome short, ridges of the endostome developed. Sternum long and rather narrow. Abdomen of male narrow and five-jointed, the third, fourth, and fifth segments consolidated. Eyestalks very small, retractile within the orbits. Antennules longitudinally folded. The antennæ lie in the inner hiatus of the orbit; their basal segment is but slightly enlarged, not filling the hiatus at the inner angle of the orbit, nor attaining to the front, subcylindrical, unarmed, imperfectly fused with the carapace; the second segment is longer and slenderer than the first, the third segment about equal to the second in length, but slenderer; all these segments are furnished with long and coarse setæ; the whole antenna is less than one half as long as the carapace. The ischium of the outer maxillipeds is produced at its antero-internal angle; the merus of the same appendages is rounded at the antero-external angle, obliquely truncated but not emarginated at the antero-internal angle, where it articulates with the following segment. Legs of moderate length. Right and left chelipeds very unequally developed in the male. Dactyli of ambulatory legs styliform, straight, slender, longer than the penultimate segments.

The pentagonal shape of the carapace recalls the genus *Telmessus* White. But in *Telmessus* the front is divided by a median notch, the orbit is much more complete, the basal segment of the antenna sending off an external process that completely fills the hiatus at the inner angle of the orbit. In the structure of the orbit and antennæ, and in the shape of the merus of the outer maxillipeds, *Trachycarcinus* is much like *Hypopeltarium* Miers (*Peltarion* Jacq.).

Trachycarcinus corallinus, sp. nov.

Carapace irregularly pentagonal, clothed with a dark brown pubescence, and bearing flattened tubercules of ivory whiteness arranged in groups, as follows: two anterior lateral and one posterior median, on the gastric region; four, disposed in two pairs, on the cardiac region; five or six on each branchial region; and [illegible], of a crescentic shape, on each hepatic region. Each group of tubercles resembles the crown of a complex molar tooth whose cusps have been worn down to a common level. Front tridentate, the median tooth twice as long as the lateral. Walls of the orbit furnished with four teeth separated by deep hiatuses; these teeth are a preocular, median superior, post-ocular, and sub-

ocular. Antero-lateral border of carapace armed with three prominent teeth; another minute tooth just back of the largest posterior lateral tooth. Eye-stalks slender; eyes small, unpigmented, with imperfectly faceted cornea. Chelipeds asymmetrical in the male; in adults the larger claw is naked, smooth, and ivory-white, like the tubercles on the carapace; the merus has a few small teeth along its upper margin, most of them near the two ends of the segment; the upper margin of the carpus is armed with one strong tooth, and is denticulated along its whole length; the propodus is short, the immovable finger bent down at an obtuse angle with the lower border of the palm; the dactylus is furnished with small tubercles on its upper border; both fingers are armed with large blunt teeth on their opposed edges. The smaller claw is slenderer than the large claw, and its fingers are proportionally longer. In the female both chelipeds are of approximately equal size, and resemble both in size and shape the smaller cheliped of the male. The ambulatory limbs are unarmed, but clad with coarse setæ.

Length of carapace, 26 mm.; breadth, 27 mm.

Station	3353.	695 fathoms.	1 female.
"	3356.	546 "	5 males, 4 females.
"	3418.	660 "	1 male.

Family GECARCINIDÆ.

Gecarcinus malpilensis, sp. nov.

Carapace very broad and convex anteriorly, flattened and narrowed posteriorly; surface microscopically granulated; antero-lateral margin rounded, not denticulated; the median gastric furrow is well marked; the furrow separating the gastric from the branchial regions does not extend forward far enough to separate the gastric from the hepatic area; the so called genital area is separated by a pronounced groove from the branchial and cardiac regions, but not from the gastric; there is a deep indentation at the anterior extremity of the lateral genital furrows; the furrows bounding the cardiac region on either side are moderately developed. Front deflexed at right angles to the axis of the body, deep, concave above the margin, margin not reflexed, granulated. The merus of the outer maxillipeds is five-sided, outer side convex, distal slightly notched, antero-internal straight and parallel to the long axis of the body, forming an obtuse angle with the postero-internal margin, which is slightly concave. Merus and carpus of chelipeds devoid of spines or teeth. Dactylus of the ambulatory legs furnished with six rows of spines.

Length, 55 mm.; breadth, 76 mm.; width of hind border of carapace, 19 mm.; width of front, 11 mm.; depth of front, 7 mm.

Malpelo Island, March 5. 1 male.

This species is very distinct from any previously described. Compared with the previously known species from the Pacific coast, it is nearest to *G. quadratus*

De Saussure, but the outline of its carapace is very different; in this regard it is similar to *G. ruricola* from the eastern coast. Moreover, the front is narrower, deeper, and bent down at a sharper angle than in *G. quadratus*, and the merus of the outer maxillipeds is very different in shape from that of *G. quadratus* or any other known species.

Family PINNOTHERIDÆ.

Pinnixa panamensis, sp. nov.

Male. — Carapace short and very broad, smooth and punctate for the most part, granulated at the sides. The lateral angles form a prominent shoulder, back of which the carapace diminishes rapidly in width. A transverse depression involves the hinder part of the gastric and the fore part of the cardiac regions. This depression is bounded behind by a ridge which extends across the carapace between the bases of the last pair of thoracic appendages. Back of this ridge the carapace is deflected at an angle of about forty-five degrees. Front depressed, divided by a median notch into two not prominent lobes; margin setose. The chelipeds are small, with very robust carpus and hand, destitute of spines, but furnished with some setæ along their edges; carpus squamose on the anterior and superior parts of the outer side; propodus not broader than the carpus, compressed laterally; a row of tubercles along the superior border forms a sort of crest; a longitudinal row of setiferous squamous tubercles runs lengthwise of the hand from the proximal end, stopping short of the base of the immobile finger; the surface between this and the dorsal crest is thickly beset with tubercles, but below it the surface is almost smooth down to a row of tubercles which runs along the inferior margin; immovable finger straight, the dactylus closing against it throughout its length; dactylus furnished with long setæ on the upper margin; no prominent teeth or tubercles on the cutting edge of either finger. First and second ambulatory limbs of moderate length, nearly naked, with slender and straight dactyli; last three segments tuberculate on superior margin. Third pair very much enlarged; the merus has a convex anterior border, and is pubescent on the anterior third of the upper surface; posterior margin double, spinulose. Fourth ambulatory legs very small, not reaching beyond the distal end of the merus of the third pair; upper surface smooth. Dactyl of penultimate and last pairs of legs short, acute, set at an angle with the propodi so as to form prehensile hooks. End joint of abdomen broader than the preceding joint, semicircular. The dactylus of the outer maxillipeds articulates with the propodus near the distal end of the latter. The carapace is 5 mm. long by 10 mm. broad.

The female differs from the male, the carapace is more highly polished, the transverse depression [illegible] pronounced, and the appendages are more thickly clothed with setæ. Length of carapace, 6.3 mm.; breadth, 13 mm.

Panama, March 12. 4 males, 6 females ovig.

Family MATUTIDÆ.

Osachila lata, sp. nov.

Carapace laterally expanded; three low obtuse protuberances on the gastric region, one on the cardiac, three or four on the branchial. Front prominent, bilobed, the lobes separated by a completely closed fissure. Antero-lateral margin of carapace sharp; behind the point where the subhepatic ridge joins the margin, the margin is divided into five obscure lobes, each of which is denticulate. Merus of chelipeds tuberculous along the upper edge and outside of it; carpus tuberculate externally, distal and superior margins produced to a cristiform tooth which continues back upon the carpus the crest on the superior border of the propodus; propodus tuberculate on the outer face, superior border denticulate and cristate. Edges of ambulatory limbs slightly cristate, dactyli pubescent on distal portion.

Length, 24.5 mm.; breadth, 32 mm.

Station 3427. 80 fathoms. 1 male.

Family DORIPPIDÆ.

Æthusa ciliatifrons, sp. nov.

Carapace broader than long, branchial regions much inflated; surface granulated on the branchial and cardiac regions, pubescent on the gastric region. Front and anterior part of the lateral border ornamented with long upturned cilia. Front between the orbits divided by a triangular median sinus and two slightly shallower lateral sinuses into four triangular teeth of equal length. Branchio-cardiac lines deeply impressed, meeting together in the median line in front of the heart. Eyes small, mounted on very short peduncles, just reaching, when extended, to the angles of the orbital sinuses. Chelipeds equal, small and slender; chela smooth, not more robust than the carpus; fingers longer than the palm, laterally compressed, curved inward, longitudinally grooved, thin prehensile edges straight and regularly denticulated. Ambulatory appendages very long (the second longer than the first), naked and minutely granulated; propodus slightly shorter than the merus, compressed, grooved longitudinally on both the upper and lower faces; dactylus one half longer than the propodus, flattened, curved, grooved and ribbed longitudinally, its upper edge very sharp. Last two pairs of thoracic limbs densely clothed with setæ. Sternum rather coarsely granulated. Conspicuous red transverse bands adorn the chelipeds and first two pairs of ambulatory appendages.

Length of a male (carapace), 26.5 mm.; breadth, 29.5 mm.

Station 3387. 210 fathoms.
" 3389. 153 "
" 3391. 259 "
" 3396. 127 "

Æthusa pubescens, sp. nov.

Carapace a little broader than long, densely pubescent; frontal margin ciliated; cardiac area open in front, the branchio-cardiac lines not meeting one another in the median line; front four-toothed, the median teeth more widely, but less deeply, separated from each other than from the lateral; the antero-lateral angles reach the level of the frontal teeth. Eyes as in the last described species (*Æ. ciliatifrons*). Chelipeds equal, small, with pubescent merus and naked carpus and hand; fingers longer than palm, compressed, curved, gaping at base. Ambulatory appendages similar to those of *Æ. ciliatifrons*, but free from granulation. Abdomen (of female) very broad, pubescent.

Length, 26 mm.; breadth, 29 mm.

Station 3367. 100 fathoms. 1 female.

This species resembles *Æ. ciliatifrons*, but the median notch of the front forms a more open angle in *Æ. pubescens*, and the sinus separating the front from the external orbital angle is not so deep. The branchio-cardiac lines do not meet in front of the cardiac area, and the cardiac area is not so much sunken below the level of the branchial regions; the branchial areas, moreover, are not so convex, nor is the cardiac region so uneven. The whole surface is densely pubescent, and the abdomen of the female is much broader. The fingers too are different, inasmuch as they are separated by quite an interval at base. The first and second pairs of ambulatory limbs are imperfect in the only specimen at hand, but they are very similar, as far as they go, to the corresponding appendages of *Æ. ciliatifrons*.

Æ. pubescens may prove to be the full-grown state of *Æ. lata* Rathbun, the description of which has just appeared in Proc. U. S. Nat. Mus., Vol. XVI p. 258, 1893.

Æthusina smithiana, sp. nov.

In this species the carapace is longer than broad, and is not much narrowed anteriorly. The front is four-toothed, the middle pair of teeth large, triangular, separated from one another by a wide triangular sinus which is broader than the antennular sinus; between these teeth the margin is bent down till it meets the epistoma below; the lateral teeth of the front are spiniform and shorter than the middle teeth. The surface of the carapace is clothed with a short pubescence, and is lightly granulous; the branchio-cardiac grooves are well marked. The post-orbital teeth are spiniform, and they project far beyond the extremity of the small eyestalks. The eyes are smaller than the extremity of their peduncles. The chelipeds are equal, small, naked but granulated; the merus cylindrical, the carpus short and rounded; the hand [illegible] equal in length to the body of the chela, compressed, prehensile edges sharp and not provided with distinct teeth or tubercles. The ambulatory legs are nearly naked, the second pair more than twice the length

of the carapace, the dactylus longer than the propodus. The last two pairs of legs terminate in short recurved claws, which are setose on the posterior edge. The sexes do not seem to differ in any marked degree.

Length of carapace (male), 9.3 mm.; breadth, 8 mm.

Station 3370. 134 fathoms. 3 females.
" 3380. 899 " 2 males.

This species is nearly related to *Æ. abyssicola* Smith, but its carapace does not diminish so much in width anteriorly, the external frontal spines are less developed, the external orbital spine is much longer and brought forward so that the orbits face more to the front. From *Æ. challengeri* Miers it differs in the greater development of the frontal and external orbital spines.

Cymopolia tuberculata, sp. nov.

Carapace very broad, subpentagonal, branchial regions swollen. Front four-toothed, the teeth blunt, separated from each other by narrow sinuses which are rounded at the bottom; the two middle teeth are longer than the lateral ones, and the median sinus is deeper than the two lateral. The antero-lateral margin of the carapace is four-toothed, counting the prominent tooth at the external angle of the orbit; the posterior tooth of the series is the smallest. The upper margin of the orbit has three deep fissures defining two triangular teeth; the lower margin of the orbit has two fissures enclosing a broad truncate tooth or lobe; there is also a broad and prominent lobe just below the inner orbital angle; above this lobe is a single tooth at the inner angle. The surface of the carapace is ornamented with granulated tubercles; the parts between the tubercles are more finely granulated, and when viewed under a lens are found to be furnished with fine hairs. The chief tubercles are disposed as follows: one pair on the frontal region behind the margin; four in a transverse row on the anterior part of the gastric area, and five on the posterior part of the same area arranged thus :˙:; of these the posterior pair is the smallest; four in a transverse line on the cardiac region and one median behind the transverse series; about six on each branchial area; six just anterior to the straight posterior margin of the carapace (three on each side). There are three small tubercles on each eye-stalk near the margin of the cornea. The chelipeds are small, slender, equal; the carpus tuberculose, the fingers as long as the hand proper, curved downward and inward, crossing at the tip, their prehensile edges finely denticulate in small specimens, nearly entire in larger ones. The second and third ambulatory limbs are very long, the second slightly longer than the third; their merus joints are granulated and costate above, and armed with a prominent spine at the antero-distal angle and a smaller one each side at the point of articulation with the carpus; this holds good of all three pairs of ambulatory appendages; the carpi are carinate on their anterior margin, with a vestige of a tooth at each end of the carina; the anterior edge of the propodus is also carinate. The ambulatory legs are ornamented with trans-

verse bands of red, three of which cross the merus. The abdomen and sternum are granulated.

Length, 13 mm.; breadth, 18 mm.; length of ambulatory leg of second pair, 34 mm.; merus of do., 9.3 mm.; carpus, 5.6 mm.; propodus, 9 mm.; dactylus, 7.5 mm.

Station 3355. 182 fathoms. 4 males, 1 female.

Cymopolia zonata Rathbun (Proc. U. S. Nat. Mus., XVI. 259, 1893), lately described from the Gulf of California, 40 fathoms, differs from *C. tuberculata* as follows. The carapace is narrower and more quadrangular. The median lobes of the front are small and inconspicuous, while the lateral lobes are very broad and are separated from the median lobes by a slight, shallow notch. In *C. tuberculata* the four frontal lobes take on the form of prominent triangular teeth, clearly separated from each other by deep triangular sinuses. The antero-lateral margin of the carapace is three-toothed in *C. zonata*, four-toothed in *C. tuberculata*. The tubercles near the posterior margin of the carapace are more elongated in the former species than in the latter. The hand of the former is much broader, and is armed with prominent spiny tubercles. Finally the meri of the ambulatory legs are much shorter in *C. zonata*, and are armed at the distal end with a blunt triangular tooth, while in *C. tuberculata* this tooth is transformed into a long sharp spine, and a pair of smaller spines is present, one on each side of the proximal end of the carpus.

Family RANINIDÆ

Raninops fornicata, sp. nov.

Carapace very convex from side to side, naked, smooth or nearly so, punctate. Rostrum acute, lightly carinate, the carina extending backward for a short distance on the carapace. Superior margin of orbit armed with three acute teeth, the second of which is curved forward; the anterior tooth is separated from the rostrum by a deep rounded sinus, from the second tooth by an angular notch; the second tooth is separated from the third by a nearly straight interval; the third tooth lies some distance in front of the posterior end of the orbit. Back of the orbit there is a strong procurved spine on the margin of the carapace. Eyestalks compressed, equal in length to one half the width of the carapace. Second segment of the third maxilliped equal to the third joint, crossed by a piliferous line; third segment notched at the antero-internal angle. Chelipeds: merus unarmed, microscopically spinose above, setose below; carpus minutely rugose-spinulose, the superior distal angle projecting as a sharp tooth; propodus lightly rugose, upper and lower borders margined, unarmed, palmar edge irregularly and inconspicuously toothed; dactylus without any prominent tooth. The dactylus of the fourth pair of legs has a very [illegible] internal border, the dactylus of the fifth is long, narrow, and spatulate. Abdomen [illegible], telson obtuse at the end.

Length of carapace, 12 mm.; breadth, 8.6 mm.

Station 3369. 52 fathoms. 1 specimen.

Family LITHODIDÆ

Rhinolithodes cristatipes, sp. nov.

The carapace is subtriangular in outline, its surface devoid of setæ, but covered with low squamiform tubercles; the whole gastric area is raised into a conical prominence; there is also a prominent crescentic rounded ridge on each branchial region, enclosing the cardiac area in a deep fossa open only behind. The rostrum is straight and conical, with a vertical plate projecting below from the proximal half down between the eyestalks; this plate is toothed anteriorly but does not reach forward nearly to the tip of the rostrum. The antero-lateral margin of the carapace is five-toothed; the second, third, and fourth of these teeth give rise to long thread-like cilia. There is another tooth at the angle between the postero-lateral and posterior margins; posterior margin straight. The upper surface of the eyestalk is covered with small tubercles and a blunt spine projects over the cornea. The movable scale of the antenna is spiniform and bears two blunt spinules on the outer side and two smaller ones on the inner. The chelipeds are unequal (the right being the larger); coxa granulated, setose on the lower inside margin; lower margin of the merus armed with three or four blunt teeth, superior margin toothed, internal distal border setose, external distal border forming a bilobed crest; outer face of carpus squamous, margins cristate, the internal crest expanded and cut into setiferous lobes; propodus tuberculated without, smooth within, toothed and setose on superior margin; immobile finger, as well as the dactylus, excavated within, setose; the larger claw has blunt teeth on the fingers, while the fingers of the smaller claw have nearly straight cutting edges. The ambulatory appendages have cristiform anterior margins from the merus to the propodus inclusive; the crest of the carpus is entire, but that of the merus is bilobed, of the propodus trilobed; the posterior margins of these appendages are dentate and more or less setose, the dactyli are provided with curved acute black tips, and with pencils of hair especially on anterior margins. The abdomen is indurated, with three rows of tuberculated plates.

Length of carapace, 16.5 mm.; breadth, 16.5 mm.

Station 3354. 322 fathoms. 1 male.

I have seen neither specimen nor figure of the type of this genus, *Rhinolithodes wosnesenskii* Brandt, from the coast of Alaska, and the specimen above described possibly does not belong to the same genus. Brandt's generic diagnosis (Bull. Phys.-Math. Acad. Sci. St. Pétersbourg, VII. 174, 1849) appears to include specific as well as generic characters. The specimen above described conforms to Stimpson's diagnosis of the genus (Proc. Acad. Nat. Sci. Phila., 1858, p. 231): "Abdomen scutis triseriatis obsessum. Antennarum aciculum margine spinosum. Pedes mediocres."

Echinocerus diomedeæ, sp. nov.

Carapace subpentagonal, gastric and branchial regions inflated, the whole surface beset with tubercles which give rise to minute setæ. There is one rather more prominent tubercle in the depression on each side of the gastric area. Rostrum short, three-spined; one of the spines is median and inferior, two are paired near the base above; in one of the two specimens obtained the median spine is toothed below. The antero-lateral margin of the carapace is irregularly toothed. Eyestalks spinulose above, with one prominent spine projecting forward over the cornea. The movable scale or spine of the antenna is spinulose on each side (four or five spines on each margin). The merus of the cheliped bears a spine on the inner side at the distal end; the carpus is smooth outside, the inner border expanded into a seven-toothed crest setose within, the outer border straight, naked, and keeled; the chelæ are of unequal size (the right being the larger), setose, spiny on the upper edge; fingers spoon-shaped within, setose and somewhat gaping. Ambulatory appendages: the meri are spinose on their edges; the anterior border of the carpus of the first pair is furnished with a crest whose edge is even and entire; the propodus of the first pair is crested along the proximal half of its anterior border, while the distal half is armed with two or three teeth; the carpus and propodus of the second and third pairs are toothed on the anterior margin, the propodus of the third pair is also toothed on the posterior margin; all the segments are hirsute, especially the dactyli. When the legs are closely folded against the sides of the carapace a wide interval is left between the carpi of the cheliped and first pair of ambulatory appendages, bounded by the opposite crests of these segments, and forming a passage for the admission of water to the gills. This orifice is similar to that seen in *E. foraminatus* Stimps., but it is not so perfectly formed The apex of the abdomen (in the female) is turned to the right (most strongly in the larger specimen); the marginal plates are wanting on the left side; all the abdominal appendages excepting the first are aborted on the right side.

Length, 64 mm.; breadth, 71 mm.

Station 3384. 458 fathoms. 1 female.

Station 3394. 511 fathoms. 1 female ovig.

In this species the acicle of the antenna is spinous on the margins only, as in *E. foraminatus* Stimps.

Paralomis aspera, sp nov.

Carapace pentagonal, as broad as long; gastric, cardiac, and branchial regions well defined and prominent; whole surface of carapace and abdomen thickly beset with papillæ or tubercles, each one of which is encircled with a crown of stiff setæ. Rostrum short, indistinctly tripartite, multispinose A sharp dark tipped spine at the external orbital angle, another at the antero-lateral angle of the carapace, and four or five, irregularly arranged, on the margin of the branchial region.

The dorsal face of the second abdominal segment consists of a single plate, undivided by longitudinal sutures, with a deep depression on each side of the middle. The following segments are unsymmetrical on the two sides of the unique type specimen (female), the abdomen being twisted to the right. The lateral margins of these segments are laciniated.

Eyestalks spinulose above; eyes very black, with downward aspect. Distal segment of antennule much longer than the antecedent segment, tuberculous above. Antennæ of moderate length; outer margin of first segment spinulose; second segment spinulose, and produced on the outer side to a long spine; movable acicle reaching to the distal end of the peduncle, spinose, the longer spines marginal, one spinule on the lower side and another on the upper side near the base; penultimate and ultimate segments of peduncle bear small setiferous tubercles. Right cheliped more robust than its fellow, thickly beset with strong spines. Ambulatory legs long, robust, spinose like the chelipeds; their basal segments are wellnigh covered by the overlapping margin of the abdomen (in the female).

Length of carapace, 113 mm.; length of rostrum, 9 mm.; breadth of carapace, 113 mm.; length of posterior ambulatory legs, 255 mm.; merus, 68 mm.; carpus, 39 mm.; propodus, 72 mm.; dactylus, 56.5 mm.

Station 3353. 695 fathoms. 1 female.

This species, like the one next described, is much longer legged than *P. granulosa* (Jacquinot), the type of the genus. In this regard it is more like the two "Challenger" species described by Henderson. The specimen above described was infested with a huge *Peltogaster* 36 mm. in breadth.

Paralomis longipes, sp. nov.

Male. — Carapace triangular; gastric, cardiac, and branchial regions well defined, protuberant; the most prominent part of the cardiac area reaches a higher level than the branchial areas; whole surface of carapace thickly covered with blunt papillæ; viewed under a lens each tubercle is seen to be encircled with a ring of short, stiff setæ; one of the tubercles, situate in front of the centre of the gastric region, assumes a spiny form. Rostrum furnished with three prominent spines, one median and inferior, two lateral and superior; the latter are not so long as the inferior spine; there is, too, a spinule on the lower side of the inferior spine, and a still smaller one above, between the roots of the superior pair. There are two pairs of long spines on the anterior margin of the carapace, one at the external orbital angles, the other at the antero-lateral angles of the carapace. There are also three or four prominent spines on the side of each branchial area. Eyestalks spinulose above. Basal segment of the antenna armed with an external spine, the second segment with several spines, the most prominent of which is on the outer side; acicle furnished with five prongs or spines, the largest median, the others lateral; flagellum much longer than the carapace. Cheliped of moderate size (the right one has been lost from

the only male specimen obtained), coxa tuberculate on the lower face, the following segments armed with strong spines, fingers excavated within, slightly gaping, penicillate, cutting edges entire. Ambulatory appendages very long, second and third pairs of about equal length and longer than the first pair; all of them armed, like the chelipeds, with spines; the spines tend toward a regular arrangement in longitudinal rows, and the spaces between the spines are smooth and naked, i. e. nearly free from spinules, tubercles, or setæ. Second segment of abdomen composed of a single calcified plate, marked by a deep hollow on each side of the middle; the other segments of the abdomen are of a leathery, semi-membranaceous consistency, and are made up of five longitudinal rows of plates, viz. one median row, flanked by a row on each side, the latter in turn bounded externally by a marginal series; whole surface of abdomen verrucose.

Length of carapace, including rostrum, 84 mm.; breadth, 78 mm.; breadth between the antero-lateral angles of carapace, 34 mm.; length of last ambulatory appendages, 242 mm.; merus, 76 mm.; carpus, 36 mm.; propodus, 64 mm.; dactylus, 47 mm.

In the female the right chela is larger than the left, and the prehensile edges of the fingers are furnished with blunt teeth. The abdomen is asymmetrical, the apex turned to the right, the marginal plates absent from the left side; the right side bears but one ovigerous appendage (the first). The abdomen nearly conceals the basal segments of the thoracic legs, which in the male are almost entirely exposed.

Station 3371. 770 fathoms. 1 male, 1 female ovig.

The egg measures 2 mm. in diameter.

Lithodes panamensis, sp. nov.

Carapace subpyriform, of about equal length and breadth; gastric and branchial regions very convex; a deep depression on each side at the anterior limit of the branchial areas, and another between the gastric and cardiac areas. Rostrum cylindrical, terminating in three spines or teeth, one of which is median, the other two lateral; a long horn, slightly upcurved, is given off from the lower side of the proximal end of the rostrum. The whole surface of the carapace is rough with low warty protuberances; the gastric region bears two pairs of spines, the anterior pair separated by a greater interval than the posterior pair. Two small spines on each branchial area, and two on the intestinal region. The orbit is bounded externally by a prominent spine, and there are five more spines on the lateral border of the carapace, viz. one at the antero-lateral angle, one on the hepatic region, and three on the branchial. Besides these there is a rudimentary lateral spine near the anterior limit of the branchial region. The posterior margin of the carapace is tuberculated, not spinose. The third segment of the antennular peduncle is equal to the first segment in length, and considerably longer than the second segment. The

antennæ are about equal in length to the carapace without the rostrum; the second segment is armed with a long and sharp external spine; there is, moreover, on the antenna of the right side a movable thorn-like acicle equal in length to the last two segments of the peduncle together; the acicle is armed with a small tooth on the external margin midway between the base and the tip. There is no trace of an acicle on the left antenna. As the type specimen is the only one obtained, it is impossible to tell whether the acicle is normally present or absent. The last segment of the peduncle is nearly twice as long as the penultimate segment. The chelipeds are furnished with scattered tubercles, a few of which assume a spiny form. The left cheliped is rather slenderer than its fellow. The ambulatory legs are long and rather slender, their meri sparsely furnished above with tubercles, which tend to a spiny form on the anterior and posterior margins; at the distal end of the anterior margin of the meri there is a prominent spine-like tooth; the carpi and propodi are armed with teeth, chiefly on the anterior margins; the dactyli are equipped with four short spines (two superior and two lateral) near the proximal end. The abdominal segments (of the female) are roughened by low tubercles, and dentate on their margins. The lateral teeth of the marginal plates of the right side are drawn out into long spines. The tergal plate of the second abdominal segment is completely fused with the epimera, showing no trace of an intervening suture. The marginal (episternal?) plates of this segment are bounded within by a distinct suture.

Length of carapace, excluding rostrum, 79 mm.; rostrum, 14 mm.; breadth of carapace, 79.5 mm.; length of posterior pair of ambulatory legs, 193 mm.; merus, 58.5 mm.; carpus, 31 mm.; propodus, 54 mm.; dactylus, 33 mm.

Station 3384. 458 fathoms. 1 female.

This species finds its nearest relative in *L. murrayi* Henderson (Rep. Challenger Anomura, p. 43, Plate IV.), from the distant Prince Edward Island in the Southern Ocean. The latter species differs from *L. panamensis* in having a much longer rostrum, which is forked at the end, a more oval and spiny carapace, shorter external antennal spine, more spinose legs, etc.

Family PAGURIDÆ.

Cancellus tanneri, sp. nov.

Differs from *C. canaliculatus* (Herbst) in having a much shorter and broader abdomen, in the lobate character of the marginal crests of the first and second pairs of legs, in the pubescence of the thorax and abdomen, and in the shortness of the antennæ. From *C. typus* M. Edw., it is distinguished by having the anterior border of the carapace less deeply incised on either side of the rostrum, and the telson squarely truncated posteriorly, not notched in the middle; the coxæ of the last pair of legs, too, present a very different shape, since they lack the prominent anterior lobe observable in *C. typus*. *C. parfaiti* A. M. Edw.

et Bouv., compared with *C. tanneri*, displays longer eyestalks, while the thorax and abdomen are less pubescent, and the coxal segments of the posterior legs are much more protuberant.

Length of carapace, 7 mm.; breadth, 5 mm.; length of eyestalk, 3 mm.

Station 3368. 66 fathoms. 1 male.

Found in a cavity in a piece of dead coral rock.

The abdomen in the unique type specimen is not quite symmetrical, but this may be an individual peculiarity resulting from the shape of the cavity in which the animal lived.

Pylopagurus longimanus, sp. nov.

Carapace smooth, naked, polished; rostrum short, triangular, subacute, advanced farther than the rounded lateral angles. Abdomen longer than cephalothorax. Eyestalks equal in length to the first two segments of the antennulary peduncle. Ophthalmic segment uncovered. Ophthalmic scales separated by a considerable interval, triangular, their tips split in a horizontal plane so that they end in two acute teeth, one above the other, the lower tooth the longer. Last segment of antennulary peduncle very long and slender (much longer than the eye-stalk). Right cheliped of enormous size, much exceeding the whole body in length; the outer face of the merus is nearly smooth, the lower and inner faces granulated; carpus very large, equalling in length all the preceding segments combined, its surface granular, the granules assuming the form of small spinulose tubercles on the dorsal face, which is limited within by a row of larger teeth. Chela irregularly oval, the external side flattened to form an opercular facet, which is thickly set with granules and surrounded with a margin of denticles. Left cheliped very small, its segments more hairy than those of the right; basal part of propodus short and swollen, the fingers long, gaping at the base; the outer or upper faces of the propodus and dactylus are granulated, and definitely bounded by a line of regularly arranged granules on the outer margin of the dactylus and the inferior margin of the propodus; the inner or lower face of the chela is pretty free from granules, but is furnished with numerous setæ, those on the dactylus being grouped in conspicuous tufts or pencils. Penultimate pair of thoracic appendages almost perfectly chelate, its rasp restricted to the distal part of the claw, broad, and composed of many rows of scales.

The legs are yellowish, banded and mottled with red.

Length of carapace, 10 mm.; eyestalk, 4 mm.; right cheliped, 34.5 mm. (merus, 8 mm.; carpus, 11 mm.; propodus, 14.8 mm.; dactylus, 10 mm.).

In younger, smaller specimens the chelipeds are shorter in proportion to the length of the body, and the major claw is shorter, broader, and of a more regular oval form. A specimen, whose carapace is 6.5 mm. long, gives the following dimensions for the right cheliped: total length, 16.5 mm.; merus, 4.5 mm.; carpus, 7.5 mm.; propodus, 7.5 mm.; dactylus, 4.5 mm.

Station 3368. 66 fathoms. 5 males.

Resembles *P. ungulatus* (Studer), but readily distinguished from that species by the great size of the right cheliped, the irregularly oval outline of the right chela, the great length of the distal segment of the antennulary peduncle, etc.

Pylopagurus affinis, sp. nov.

This species is nearly related to *P. ungulatus*, from which it differs in the following respects. the eyestalks are longer, and narrower at the distal end; the external prolongation of the second segment of the antenna is longer and slenderer; the upper margin of the carpus of the right cheliped is armed with two or three spines, the largest of which is close to the anterior border; the outer face of the carpus is smooth save where a light tubercular ridge runs along the middle. In *P. ungulatus* this face of the carpus is thickly covered with spinulose granules which assume larger proportions and a uniserial arrangement on the superior and inferior margins. On extending the comparison to the large chela, further differences between the two species become apparent. In both species the external face is flat, covered with minute spinulose granules, and surrounded by a border of sharp spines; but in *P. affinis* the marginal spines are larger and more irregular, and the flat opercular facet is not sharply defined at the proximal end by the regular arrangement of the marginal spines as in *P. ungulatus;* instead, one finds the marginal series of spines broken down at this point, thus effacing any distinct limit between the opercular face of the chela and the articular surface which connects the propodus with the carpus. The inner or lower surface of the large chela is smooth in *P. affinis*, granulated in *P. ungulatus*. The left cheliped is quite different in the two species: in *P. affinis* the several segments of which it is composed give rise to long setæ, which give the appendage a very hairy appearance when contrasted with *P. ungulatus;* the inferior border of the chela is conspicuously toothed, while in *P. ungulatus* it is entire. The ambulatory legs are more hairy in the Pacific species than in *P. ungulatus*, and their carpal joints are not so distinctly dentate on the superior border. The rasps of the fourth pair of legs are multiserial in both species. The telson is symmetrical, subcircular in outline, its posterior border convex and entire; in *P. ungulatus*, the telson has a deep and wide posterior median notch.

Length, about 12 mm.; length of carapace, 4.5 mm.

Station 3397. 85 fathoms. 1 male.

There are three simple unpaired abdominal appendages on the left side, in the type specimen. The vasa deferentia are extruded from the base of the fifth legs on each side. They appear as slender threads, the one on the right side much longer than its fellow, and twisted into a small bunch.

Pylopagurus hirtimanus, sp. nov.

This species closely resembles *P. rosaceus* A. M. Edw. et Bouv.,[1] from the West Indian seas. Compared with the type of *P. rosaceus* it presents the following differences. The eyestalks are a little slenderer, and together with the ophthalmic scales are separated by a wide interval in which the antennules lie, exposed from above. In *P. rosaceus*, on the contrary, the ophthalmic stalks and scales are closely approximated, concealing the antennules beneath. The outer face of the right chela is ornamented with conical tubercles, whose bases are expanded into circular plates; these plates are closely packed over the surface of the chela, so that no interstices are left between them; their borders are cut into a large number of minute radiating processes; on the basal half of the propodus the tubercles give rise to long setæ, which render that part of the claw conspicuously hirsute, in contrast with the distal part which is naked; furthermore, on the distal half of the propodus, especially on the concave surface of the immovable finger, the tubercular processes tend to become obsolete, leaving only the basal circular radiate plate; the bases of the conical teeth along the outer margin of the hand and the movable finger are expanded at the base into flattened roundish surfaces with radiate margins; these surfaces form a conspicuous outer border to the hand; the inner face of the hand is tuberculated. In *P. rosaceus* the tubercles of the outer face of the chela are encircled by rounded granules much less numerous than the radiating points in *P. hirtimanus;* the tubercles are so loosely arranged that numerous interstices are apparent between them; the hairs on the basal half of the hand are not so well developed as in the Pacific species; the whole outer face of the immovable finger is strongly tuberculated, the teeth of the lower margin are not expanded into conspicuous plates, and the inner face of the chela is nearly smooth. The carpus in *P. hirtimanus* is armed with larger spines on the internal margin, is more hairy, and more coarsely granulated on its inner, inferior, and outer surfaces than it is in *P. rosaceus*. The left chela is comparatively smaller than in *P. rosaceus*, is more strongly toothed along the internal margin of the propodus and dactylus, and exhibits, besides, most of the above specified peculiarities of the right claw. The primary branch of the unpaired abdominal appendages is shorter and broader than in *P. rosaceus*. The rasp on the propodus of the fourth pair of legs is uniserial, as in *P. rosaceus*.

Length of carapace of largest male, 12 mm.; length of carapace in front of cervical groove, 7 mm., breadth across the branchial regions, 9.5 mm.; length of large claw, 11 mm.; breadth of large claw, 7 mm.

Station 3367. 100 fathoms 2 males, 1 female.
" 3368 66 " 5 males, 5 females

A good deal of the color is still preserved in alcohol. The lower surface of the eyestalk is quite a deep red, while the upper surface is a pale yellow. The

[1] Mem Mus Comp Zool, XIV No 3, p. 97, Plate VII Figs. 10–17, 1893.

merus and carpus of the chelipeds and all the segments of the ambulatory legs from the ischium to the dactylus inclusive are banded transversely with bright red on a yellowish ground.

Catapagurus diomedeæ, sp. nov.

The carapace is smooth and naked, and divided into an anterior and posterior section by the cervical groove. The anterior margin projects slightly between the eyestalks, forming a blunt rudimentary rostrum. The gastric region is sharply defined, and presents an indistinct longitudinal furrow on each side of the median line; it is lightly convex in both directions. The branchial regions of the right and left sides are strongly inflated and sharply separated from each other by a re-entrant angle formed by the curving forward of the posterior border of the carapace on each side of the median line.

The eyestalks are rather long and slender, being about equal in length to the anterior section of the carapace. The ophthalmic scales are very small and minutely bifid at the tip. The third segment of the antennulary peduncle is about two thirds the length of the eyestalk, and increases in diameter from the base to the distal end; the superior flagellum is rather longer than the distal segment of the peduncle, and its enlarged ciliated basal portion forms rather more than one third of its whole length. The inferior flagellum is about one half as long as the superior, and is composed of about eleven segments. The peduncle of the antenna surpasses the eyestalk by one half the length of its distal segment; the acicle is long and slender, tipped with a few setæ; it reaches forward a little beyond the eye; the flagellum reaches beyond the tips of the ambulatory legs. The chelipeds are nearly alike in shape and size; their segments are clothed with long setæ, which assume a tomentose appearance on the chelæ; the carpus is about equal in length to the chela, its inner face is perpendicular, the inner margin of the upper side is armed with seven small spines; there is also a spine at the distal end of the superior margin of the carpus; the chela is short and thick, the fingers about the same length as the basal portion of the propodus, slightly down-curved, meeting throughout their length, working horizontally. The ambulatory legs are of nearly equal length, surpassing the chelipeds, setose, the carpus armed with a sharp tooth at the distal end of its upper side; the propodus is twice as long as the carpus, the dactylus is considerably longer than the propodus, and, like that segment, is distinctly curved; it is tipped by a small horny nail. The fourth pair of legs is but slightly subcheliform; the rasp is formed of a single row of scales. There are three small rudimentary appendages on the left side of the abdomen; the first and second of these are two-branched, the secondary branch being exceedingly minute.

The sexual tube, which issues from the coxal segment of the last thoracic appendage of the right side, is very long in this species.

Length of carapace, 5.5 mm.; abdomen, 8 mm.; cheliped, 12.5 mm.; last ambulatory leg, 17.5 mm.; ocular peduncle, 2.5 mm.

Station 3355. 182 fathoms. 1 male.

This species differs much from the more typical species of *Catapagurus*, *C. sharreri* A. M. Edw. and *C. gracilis* Smith, in the shortness of its chelipeds and ambulatory limbs, the symmetry of its chelipeds, and the length of the protruded vas deferens. It is more nearly related to *C. australis* Henderson (Challenger Anomura, p. 76, Plate VIII. Fig. 1). It would seem to have a close general likeness to *Pagurodes piliferus* Henderson, but the gills in *C. diomedeæ* are of the phyllobranchiate type.

Spiropagurus occidentalis, sp. nov.

The carapace is smooth and naked except on the sides of the branchial regions, where a few hairs arise; the branchial regions are swollen, membranaceous, and covered with a network of white lines; the cardiac region is long and narrow; the portion of the carapace in front of the cervical groove is calcified, produced in the median line anteriorly to form a short, broad, and obtuse rostrum, which does not conceal the ophthalmic segment; the lateral teeth are acute, and project as far as the rostrum does; they form a sharp demarkation between the front and the oblique antero-lateral border of the carapace.

The ophthalmic scales are triangular, with simple tips. The ocular peduncles are enlarged at the distal end, hardly overreaching the distal end of the second segment of the antennulary flagellum and the third segment of the antennary flagellum. The last segment of the antennulary peduncle is more than twice as long as the penultimate segment. The second segment of the antennal peduncle is produced externally into a long, sharp tooth; the antero-internal angle is likewise armed with a small spine; the acicle is long, sharp, curved, and furnished with setæ, as are also the several joints of the peduncle.

The chelipeds are subequal, the right chela being appreciably larger than the left; the ischium is armed with about five denticles along the internal margin; the inner margin of the merus is armed with the same number of rather larger teeth; the inner margin of both of these segments is furnished with long and slender setæ; the surface of the carpus is rough with setiferous rugæ, and is armed with scattered spinules upon its upper face and with a row of larger spines along the internal margin of the upper face. The external face of the propodus is armed with spines which are regularly arranged in five longitudinal rows; only at the distal end of the propodus, at the base of the fingers, do these spines lose their regular serial arrangement; from the bases of these spines spring long setæ; the fingers are acute, tuberculo-spinose and setose, like the hand. The fingers of the left hand are longer in proportion to the palm than those of the right hand. The ambulatory legs are rather robust, and longer than the chelipeds; their lateral surfaces are smooth; the upper margins of the carpi are armed with a row of little spines, and the corresponding margins of the propodi are denticulated; the dactyli are longer than the propodi, but not so long as the propodus and carpus combined, the anterior pair of ambulatory

legs differs from the posterior pair in having the dactylus and propodus a little shorter, and the lower edge of the merus more hairy and minutely spinulose. The telson is deeply cut by a broad median notch in its hind margin into two lobes, the left of which is the larger. The margins of both lobes are spinose.

There is (in the alcoholic specimens) a narrow red ring around both fingers near their tips, a broader band of the same color around the base of the fingers, and a red patch on the inner side of the anterior face of the hand.

Length of carapace, 6.5 mm.; greatest breadth of carapace, 6 mm.; length of ocular peduncles, 2.3 mm.

Station 3368. 66 fathoms. 1 male.
" 3379. 52 " 1 male.

This species, like *S. iris* A. M. Edw., is characterized by the spiny armature of the chelipeds. It differs from *S. iris* by having a smaller number of spines upon the anterior face of the chela, and in their arrangement in a few definite longitudinal rows, the surface between the rows being spineless and reticulated. The chela does not display the lively iridescence so striking in Milne Edwards's species, nor are the ophthalmic scales bidentate at the end. The merus of the third maxilliped is not armed with a distal spine, as in *S. iris*.

Paguristes fecundus, sp. nov.

The anterior or gastric section of the carapace is smooth in the central and hinder parts, rugose near the front, and tuberculose in the antero-lateral region, where a few of the tubercles assume a spiny form; from the tubercular surface spring long slender setæ. The anterior margin of the carapace is produced in the median line so as to form an acute triangular rostrum, which projects beyond the subacute lateral processes; between the rostrum and the lateral processes the anterior border is concave and thickened so as to form a rim. The anterior gastric lobes are clearly defined anteriorly.

The ocular peduncles are long and cylindrical, reaching considerably beyond the antennal peduncle, but not quite so far as the antennulary peduncle. The ophthalmic scales are of moderate size and bidentate at the tip, the external tooth very minute. The antennal acicle reaches almost to the end of the peduncle; it is setose, and armed with six spines, two of which form a terminal fork, the others being marginal. The external prolongation of the second antennal segment is narrow, setose, and minutely spinulose; there is, moreover, a spinule on the upper face of this segment behind the base of the acicle; the antennal flagellum is very short (about equal in length to the anterior section of the carapace). The third pair of maxillipeds are closely approximated at the base; their merus joints are armed with three or four denticles on the lower margin, and one at the distal end of the upper margin.

The chelipeds are short and of like size and shape; the merus is smooth within, rugose without; the two inferior margins are armed with minute black-tipped spinules. The carpus is tomentose and spinulose, the largest

spines occurring along the superior border; the hand is both spinulose and pubescent, but the hair is less dense upon the fingers than upon the basal portion of the hand, which is short and swollen below; the fingers are short, excavated within, and terminate bluntly in a dark corneous nail. The ambulatory limbs are pubescent, particularly on the upper and lower margins; the distal end of the merus, and also the carpus, propodus, and dactylus, are armed with numerous spines; the most prominent of these spines are arranged in a row along the upper border of the carpus and propodus; the dactylus is about equal in length to the propodus and carpus together. The legs of the fourth pair are furnished with long hairs on their upper margin, and there are a few spines on the upper margin of the carpus; the propodus is rather longer than the dactylus, and the rasping surface on its lower margin occupies two thirds of its length. The last pair of legs is much less hairy than the preceding pair; the rasping surface, which is truncate posteriorly, falls a little short of reaching the middle of the hand. The telson is divided by a pair of lateral incisions and a median one into four lobes, those on the left side the larger; the pair of terminal lobes are obscurely toothed on their margins.

Length of carapace, 9.5 mm.; breadth, 7 mm.; length of ocular peduncle, 4 mm.

Station 3368. 66 fathoms. 2 females ovig.

This species is nearly related to *P. lymani* A. M. Edw. et Bouv.,[1] of the West Indian region, and to *P. subpilosus* Hend.,[2] of New Zealand. From the former it is distinguished by the more prominent and acute rostrum which overhangs the ocular segment, by the smaller number of spines on the antennal acicle, and by the armature of the telson, the margin of which is ornamented with obscure teeth, while in *P. lymani* it is furnished with numerous spines whose tips are horny and dark colored. From *P. subpilosus* it differs in having shorter eyestalks and antennal acicle, fewer spines on the antennal acicle, a longer and narrower external prolongation of the second joint of the antenna, and a differently shaped telson.

The ovisacs of both specimens are large and filled with eggs.

Family PORCELLANIDÆ.

Petrolisthes agassizii, sp. nov.

In the shape of the carapace and the front this species bears a close resemblance to *Petrolisthes sexspinosus* (Gibbes) and *P. occidentalis* Stimps., but the transverse ridges are more broken anteriorly, while posteriorly they extend without interruption across the whole width of the carapace, being here more perfectly developed than in the two species above named. The carpus and claw,

[1] Mem Mus Comp Zool, XIV No 3, p 49, Plate IV. Figs. 13–22, 1893.

[2] Challenger Anomura, p. 77, Plate VIII. Figs. 2, 2 *a*, 1888.

moreover, are longer and narrower; the anterior margin of the carpus is three-toothed instead of five-toothed. The squames of the carpus and claw do not tend to widen out into ridges or folds either on the upper or lower face, but preserve the form of close-set imbricated scales over the whole surface, including the space between the longitudinal depressions of the carpus and along the depressed line of the propodus. The form of the carpus approaches nearer to that of *P. armatus* (Gibbes), but the present species may be readily distinguished from *P. armatus* by the prominent rugæ of the carapace and the squames of the chelipeds. From *P. edwardsii* (Sauss.) it is distinguished by its longer chelipeds, by the ridges of the hinder part of the carapace extending clear across the carapace without interruption, etc. The ridges of the frontal lobes are much more strongly developed in *P. agassizii* than in any of the allied species.

Carapace 5 × 5 mm.; cheliped, 34 mm.

One male, taken with *Petrolisthes occidentalis* Stimps. on the reef at Panama, at low tide, March 12.

Pachycheles panamensis, sp. nov.

Carapace subcircular, of equal length and breadth; upper surface flattened, granulate, and setose, especially on the gastric and anterior part of the branchial regions; posterior portions of the branchial regions lightly rugose. Front broad, produced to a rounded median lobe, lateral portions straight, inner orbital angle rounded, not produced; outer orbital angle projecting as a triangular tooth between the eye and the base of the antenna. Lateral border of the carapace with a concavity behind the antenna; the margin is slightly raised as a rim which is lost in one of the branchial rugæ before reaching the hind border of the carapace; hind border slightly concave. Chelipeds: unequal, the right being the larger; upper surface of the merus rugose and setose, under surface smooth, internal distal angle produced as a denticulated tooth; carpus short and broad, upper surface tuberculous and setose, internal border armed with a large tooth at the base, followed by one or two smaller teeth, lower surface smooth and naked; upper surface of the propodus furnished with small tubercles which bear stiff bristles, inner margin rounded, not toothed, outer margin granulated, lower surface convex, naked and polished near the centre (where the surface is reticulated in the larger claw), squamoso-granular and setose near the edges; fingers gaping, crossing at tips, toothless on both the inner and outer margins (or at most slightly denticulated on the outer margin). Ambulatory appendages setose.

Length of carapace, 6.5 mm.; breadth, 7 mm.; breadth of frontal margin, 2 mm.

Panama, March 12. 1 female ovig.

Pachycheles rudis Stimps. is a larger species, with the posterior margin of the carapace more concave (the concavity having almost the shape of a triangular

notch); the carapace and chelipeds are less setose than in *P. panamensis*, the anterior margin of the carpus not prominently toothed, and there is a strong protuberance near the middle of the upper surface of the propodus. In *P. tuberculipes* Lockington, the central part of the front is triangular and deeply furrowed along the median line, the chelipeds and ambulatory legs are knobbed so as to present "a mass of tubercles above." *P. panamensis* appears to be near *P. barbatus* A. Milne Edwards, from the Azores, but in the latter species the front is broader and the carpus more denticulated.

Family GALATEIDÆ.

Pleuroncodes monodon (M. Edw.)?

Compared with Milne Edwards's figure of *P. monodon* (Ann. Sci. Nat., 3 sér. Zool., XVI. Plate XI. Figs. 6–9), the "Albatross" specimens present a more obese appearance; their greatest width is across the cardiac region, while in the figure of *P. monodon* it is near the posterior end of the carapace; the cardiac area, too, in the examples before me, is sunk below the level of the rest of the carapace, and the transverse piliferous lines are more broken at this point, as well as on the gastric region, than appears to be the case in *P. monodon*, to judge from the figure referred to. Unless these discrepancies are due to the inaccuracy of Milne Edwards's draughtsman, the "Albatross" specimens belong to a new species.

Station	3385.	286 fathoms.		16 males, 7 females.
"	3386.	242	"	9 males, 14 females.
"	3396.	259	"	2 males, 2 females.
"	3423.	94	"	18 males, 11 females.

Munida obesa, sp. nov.

In this species we see an approach to the genus *Pleuroncodes*, as the sides or latero-inferior walls of the carapace are somewhat swollen, so that they show a little when the animal is viewed from above. The basal joint of the antennæ, too, is more exposed from above than it is in the typical species of *Munida*. The lateral rostral spines, or supra-ocular spines, are curved upward more than the median rostral spine, and the three are nearly parallel, the lateral spines reaching about half way to the tip of the median; all three are microscopically spinulose on their upper edge. There are two pairs of spines on the anterior part of the gastric region in line with the lateral rostral spines. Of these two pairs the anterior is the larger. There is also a longitudinal line of spinules in the median line between the two pairs just spoken of. There are, in addition to these, several small spines irregularly arranged on each side of the gastric region. The cardiac area is somewhat sunk below the level of

the surrounding parts; its anterior margin is denticulated, with a larger spine on each side. The lateral margins of the carapace are armed with ten or eleven spines, the one on the antero-lateral angle being the longest. The second abdominal segment is ornamented with a transverse row of eight small spines. The other abdominal segments are normally destitute of spines, but in a few of the many specimens before me there are two or four small spinules on the third segment. The pleuræ of the third, fourth, and sixth abdominal segments are acute, the rest blunt. The eyes are large, and are provided with rather long cilia on the edge of the cornea. The basal joint of the antenna is armed with a long and sharp spine which reaches forward beyond the eyes; the second joint also has a long spine on each side. The chelipeds are long and hairy; the merus, carpus, and basal part of the propodus are spiny, the fingers long, slender, the cutting edges straight and finely spinulose. The ambulatory appendages are setose, the upper and lower edges of the merus are spinulose and there is, moreover, a row of spinules on the outer surface, this external line of spinules being best developed on the proximal end of the segment. The carpus is armed with small spines on the upper margin, and one spine on the distal end of the lower margin; the penultimate and terminal joints are unarmed.

Length, 65 mm.; length of carapace, 34.5 mm.; breadth of carapace between epimeral sutures, 21 mm.; length of rostrum, 11 mm., length of cheliped, 84 mm., merus, 26 mm., carpus, 10 mm., basal portion of chela, 18 mm., dactylus, 21 mm.

Station 3389. 210 fathoms. 2 males, 7 females.
" 3355. 182 " 5 young.

Munida refulgens, sp. nov.

In this species the setæ on the ridges of the thorax and abdomen and on the legs are resplendent with iridescent hues. The rostrum is long, triangular in cross section, the upper surface scabrous, the lateral margins armed with two to four spines which are generally placed unsymmetrically on the two sides. The supra-ocular spines are short. There is a transverse line of spinules back of the base of the rostrum, the two which lie on either side of the median line being larger than the others. Seven marginal spines on each side of the carapace, the ones at the antero-lateral angles the largest. There are no spines on the abdominal segments. The abdominal pleuræ are acute. The basal joint of the antenna has a plate-like expansion, but is not spinose; the second joint is furnished with an external spine. Chelipeds very long, squamose, and clothed with silky setæ; the merus has a row of spines on the upper margin, another on the inner side, and a row of smaller ones on the outer side; the carpus is provided with three or four spinules at the distal end; the chela is slender, the outer finger flattened, ribbed above, the outer edge rather convex and expanded toward the base; cutting edges of fingers finely denticu-

lated. The anterior border of the merus and carpus of the ambulatory appendages is spinose. The general color in life is red. In the alcoholic specimens the color is retained in the chelæ and particularly in the rostrum.

Dimensions of largest specimen (male). Length, 91 mm.; length of carapace, including rostrum, 43 mm.; breadth of carapace, 34 mm.; length of cheliped, 211 mm., merus, 90 mm., carpus, 15 mm., basal part of chela, 56 mm., dactylus, 42 mm.

Station	3367.	100	fathoms.	13 males, 18 females (7 ovig.).
"	3378.	112	"	15 males, 19 females (14 ovig.).
"	3379.	52	"	1 young.
"	3427.	80	"	1 young.

In *M. iris* A. M. Edw., the setæ are iridescent, as in this species, but the rostrum lacks the lateral spines and the supra-ocular spines are much longer, reaching beyond the eyes; from *M. irrasa* A. M. Edw., our species differs in the shape of the hand, in the relatively shorter median rostral spine provided with lateral spines, etc.

Munida propinqua, sp. nov.

The carapace of this species is rather flat; the rostral spines are scabrous, the lateral reaching to a point beyond the eyes; there is a prominent spine on the gastric area behind each lateral rostral spine, another on each side behind and external to these, and a pair of very small ones on the median line at the base of the rostrum; besides these there are about four small spines on the anterior half of the carapace. The anterior lateral angle of the carapace is truncated, the lateral border seven-spined. The pleuræ of the abdomen are rounded, short, and broad; the second abdominal segment is furnished with a transverse row of about eight spines, the rest of the segments being destitute of spines; the terga of the second to the fourth segments are very smooth behind the central transverse fossæ. The first joint of the antenna is armed with a long spine, the second joint with one on each side. There is a minute spine at the antero-inferior angle of the carapace. The chelipeds are robust, setose, and spiny; merus spiny on upper and inner parts; carpus spiny on all sides; The hand is furnished with two rows of spines on the lower side, another along the middle of the outer face, and three irregular series along the upper side. Both the fingers are spinulose. Ambulatory limbs setose, spinose along the superior and inferior edges. In small specimens the lateral spines of the rostrum may be shorter than the eyestalks.

Length, 84 mm.; carapace (including the rostrum), 45.5 mm.; breadth, 26 mm.; length of cheliped, 96 mm.

Station	3384.	458	fathoms.	11 males, 6 females (1 ovig.).
"	3394.	511	"	1 male.
"	3404.	385	"	1 male juv.

This species resembles *M. miles* A. M. Edw., but the carapace of *M. propinqua* is flatter, the cardiac area is more distinctly circumscribed by a furrow.

the abdomen bears spines only on the second segment, and the abdominal segments are not so much sculptured.

Munida gracilipes, sp. nov.

Carapace rather flat and quadrangular. Lateral spines of rostrum less than one half the length of the rostrum, shorter than the ocular peduncle. Four spinules on the gastric area arranged in the form of a square, — two behind each lateral rostral spine ; a longitudinal row of obsolescent spinules in the median line from base of rostrum to the cardiac area ; one spine on the cardiac region, a pair on the intestinal region, and one on each side of the cardiac region just back of the cervical suture. The lateral margins of the carapace are armed with about seven spines, the first of which is the largest. The second abdominal segment is armed with a transverse row of six spines, the third with a row of four, the fourth with a row of four and one median spine behind the transverse row. This is the normal arrangement, but in one specimen out of the four there is an additional pair of spines on the second and third segments back of the transverse row. The pleuræ of the third, fourth, and fifth abdominal segments are acute. Eyes very large, reniform. The chelipeds are very long and slender, the merus spinose (the chief of the spines being on the inner side of the joint) ; the carpus also is spinose. The hand has about eight spines on the upper margin and one on the lower ; there are several acute spines on the outer border of the movable finger, the cutting edges of the fingers are straight, finely denticulated or spinulose.

Length, 24 mm.; breadth, 8 mm.; length of cheliped, 34 mm.

Station 3391. 153 fathoms. 4 specimens.

This species is very near to *M. stimpsoni* A. M. Edw., but the carapace is flatter, less granulated, more quadrangular in outline, with more evident transverse rugæ ; the lateral rostral horns are shorter, the eye larger, the transverse ridges on the abdominal somites fewer in number; the lateral spines of the carapace and the abdominal spines are better developed, the cardiac area narrower and bounded by more distinct furrows.

Munida microphthalma A. M. Edw.?

Bull. Mus. Comp. Zoöl, VIII. 51, 1880.

Station 3370. 134 fathoms. 1 female ovig. Length, 20 mm.

Only one specimen of *M. microphthalma* has been returned to this Museum from Paris. It is a very small specimen, without chelipeds. The "Albatross" specimen differs from this one in having the rostral median spine less upturned. The chela, compared with that of *M. microphthalma*, as figured by Henderson (Rep. Challenger Anomura, Plate III. Fig. 4), has no spine on the outer margin of the dactylus, and the row of spines on the outer face of the hand is obsolete.

M. microphthalma was taken by the "Blake" among the West Indies in 573–1030 fathoms, and by the "Challenger" in the same region in 390 fathoms, north of the Kermadec Islands in 600 fathoms, and near Ascension Island in 425 fathoms.

Galacantha rostrata A. M. Edw.

Galacantha rostrata A. M. Edw., Bull. Mus. Comp. Zoöl., VIII. 52, 1880.
Galacantha bellis Hend., Ann. Mag. Nat. Hist, 5th Ser., XVI 418, 1885; Rep. Challenger Anomura, p. 167, Plate XIX. Fig. 6, 1888.

Station 3362.	1175 fathoms.	1 male.	
" 3400.	1322 "	3 males, 2 females (1 ovig.).	
" 3413.	1360 "	1 female.	

The "Albatross" specimens differ from the typical West Indian form in the greater divergence of the lateral spines, the anterior being more nearly parallel with the axis of the body; the abdomen is smoother toward the central part of the segments; the dorsal spine of the fourth abdominal segment is smaller. There is considerable variation among different individuals, and the characters pointed out by Henderson to distinguish *G. bellis* can hardly be deemed of specific value. The color in life is red, paler and yellowish toward the middle of the carapace. *G. rostrata* has been collected in the West Indian seas in from 1098 to 1591 fathoms, and off Juan Fernandez in 1375 fathoms (*G. bellis* Hend.).

Galacantha diomedeæ, sp. nov.

Rostrum without lateral spines; distal part turned upward at an angle of less than 95° in most specimens, but in some cases the inclination is greater; basal part marginate, the margin running for some distance along the anterior edge of the carapace; a slight keel runs back from the rostrum to the median gastric spine. Gastric spine smaller than in *G. rostrata*; anterior lateral spine much longer than the posterior; there is an additional small spine on the side of the carapace, just behind the cervical suture. Anterior half of the carapace ornamented with setiferous squamous tubercles; on the posterior half of the carapace the tubercles assume the form of interrupted transverse ridges. The median spines of the abdomen are small, diminishing successively in size from the first to the third, which is obsolete in some examples. Upper surface of abdomen rather hairy, the pleuræ tuberculose, angles rounded. The legs are rough with granular setose tubercles. There are two prominent spines at the distal end of the carpus of the chelipeds, and one at the distal end of the carpus and merus of the ambulatory limbs. The antennæ are twice and a half as long as the body.

Dimensions of a female specimen. Length of body, 79 mm.; length of carapace, 39 mm.; breadth of carapace, not including the lateral spines, 25 mm.

This species runs into a well marked variety, in which the anterior lateral spines, as well as the median gastric spine, are very much smaller than in the

typical form. This variety may be called *Galacantha diomedeæ parvispina*. At one station (3429) both forms were obtained at the same haul.

This species differs from *G. rostrata*, *areolata*, *spinosa*, and *talismanii* in the rugose nature of the sculpture of the hinder half of the carapace. In the relative proportion of the anterior and posterior lateral spines it agrees with *G. spinosa*.

Station 3357.	782 fathoms.		1 female juv.
" 3363.	978	"	3 males, 3 females ovig.
" 3364.	902	"	1 female.
" 3366.	1067	"	3 males, 1 female ovig.
" 3371.	770	"	5 males, 2 females (1 ovig.).
" 3373.	1877	"	1 male.
" 3393.	1020	"	3 males.
" 3407.	885	"	2 males, 1 female.
" 3429.	919	"	1 male.
Var. *parvispina*.			
Station 3418.	660 fathoms.		1 male.
" 3419.	772	"	1 female ovig.
" 3424.	676	"	1 male.
" 3429.	919	"	1 male.
" 3435.	859	"	18 males, 17 females (6 ovig.).
" 3436.	905	"	6 males, 4 females (3 ovig.).

In both *G. rostrata* and *G. diomedeæ* there is a curious sexual difference. In the male the proximal half of the telson is furnished on each side with long amber-colored setæ, which are entirely wanting in the female. The same difference between the sexes is found in some species of *Munidopsis*.

G. diomedeæ is often infested with parasites. One of the males from Station 3371 bears a *Peltogaster*, while seven specimens (5 males, 2 females) of var. *parvispina* house a *Bopyrus* in the left branchial chamber.

The eggs of this species measure 3 × 2.5 mm.

Munidopsis[1] vicina, sp. nov.

Near *M. ciliata* Wood-Mason, from which it differs as follows. It is a very much smaller species, the adult ovigerous female being only twenty-nine millimeters long; the anterior margin of the propodus of the ambulatory appendages bears two very prominent spines. The telson lacks the pair of long and narrow plates which lie on each side of the small central plate in *M. ciliata*. As in *M. ciliata*, the carapace is covered with squamous tubercles, the rostrum is curved slightly upward, and the chela is short.

Length, 29 mm.; breadth, 9.5 mm.

Station 3360.	1672 fathoms.		1 female.
" 3382.	1793	"	1 female ovig.

[1] The genus *Munidopsis*, as here understood, includes *Galatodes*, *Orophorrhynchus*, and *Elasmonotus* of A. Milne Edwards, and *Anoplonotus* of Smith.

Munidopsis agassizii, sp. nov.

The carapace of this species is moderately convex, with a deep transverse depression across the anterior part of the cardiac area. The rostrum is long, slightly upturned, and armed near the middle with a pair of lateral spines. The gastric area has four pairs of spines, the anterior pair the largest. The cardiac area bears two or three pairs of spines. The lateral margins of the carapace carry from six to eight spines each, and there is a longitudinal series of small spines within the margin on the branchial area. A small spine is situated on the anterior margin between the eye and the antenna. The posterior border of the carapace is ornamented with six (in one specimen seven) spines. There are also several spines on the sides of the carapace below the epimeral suture. There is a very small spine over each eye. The antennæ are shorter than the body, the first joint bears a long external spine, the second joint two lateral spines, the third joint two lateral spines and one superior. The chelipeds are long and slender, the merus and carpus have no long spines, the propodus carries four spines on the upper edge and several rudimentary spinules, the fingers are spinulose, their cutting edges straight and denticulated. The ambulatory appendages have spiny meri and carpi, the longest spines being one at the distal superior border of each of these joints. The second, third, and fourth abdominal segments bear four spines each. The abdominal pleuræ are rounded.

Length, 23 mm.; length of carapace, 12.4 mm.; breadth of carapace, 8 mm.; length of rostrum, 4.5 mm.

Station 3389. 210 fathoms. 1 male, 1 female.

This species bears a general resemblance to *M. erinacea* (A. M. Edw.) and *M. spinifera* (A. M. Edw.). It differs from both these in having a flatter carapace marked by a deeper transverse depression across the cardiac area, in having a larger number of spines on the sides of the carapace, and in the presence of spines on the pterygostomian regions and a small but distinct spine over the eye. It also has strong spines on the superior edge of the hand which are wanting in *M. erinacea* and *M. spinifera*. In the possession of three pairs of gastric spines it agrees with *M. spinifera*, but differs from *M. erinacea*.

Munidopsis villosa, sp. nov.

The whole surface of the body and limbs is beset with setæ, which arise from low squamous tubercles and transverse rugæ on the carapace, and from the transverse ridges of the abdominal segments. The rostrum is triangular, the distal half upturned, cylindrical, and pointed, the proximal half naked, bold and slightly carinate in the median line. A pair of short, stout, blunt spines on the gastric region. One spine at antero-lateral angle of the carapace, one on margin of the hepatic area, and a rudimentary one on the side of the

branchial region. There is a medium spine on the second, third, and fifth abdominal segments, and a rudiment of one on the fourth. The abdominal pleuræ have rounded external angles. The eyes are freely movable and destitute of spines. The second antennal segment is armed with a prominent external spine. The chelipeds are robust, setose, and granulate ; the merus has a short superior spine and two lateral spines at the distal end; the carpus is similarly equipped, though on one side the superior spine is obsolescent ; the chela is broad and strong, the fingers excavated, denticulated on their cutting edges and at their tips. The merus of the first pair of ambulatory appendages has an external distal spine ; the carpus of all the ambulatory limbs has two longitudinal ridges, and that of the first and second pair has a spine on the upper border at the distal end of the joint.

Length, 55 mm.; breadth, 18 mm.; length of carapace, 31 mm. ; rostrum, 8 mm.

Station, 3394. 511 fathoms. 1 male.

Munidopsis hystrix, sp. nov.

Carapace setose and thickly covered with small spiny tubercles; three spines of special prominence on the gastric area disposed in the form of a triangle with apex directed backward; one on the cardiac area; two (rarely six) on the hind margin of the carapace; one on each branchial area. There is a spine at the external angle of the orbit, and the lateral margin of the carapace is spinose. The rostrum is long, lightly curved upward from the base to the tip, and armed with from two to five spines on each side ; these spines are unsymmetrically arranged on the two sides. The second, third, and fourth abdominal segments are conspicuously two-ridged; the second segment has a pair of small spines on the anterior ridge, and another pair nearer the median line on the posterior ridge; the third segment also has a pair of spines on the anterior ridge, and in some specimens a third spine in the median line on the posterior ridge. The abdominal pleuræ are truncate. The chelipeds are long, very spiny from the proximal end of the merus to the base of the fingers; the chief spines of the propodus are on the upper margin of the segment ; there are two spines near the base of the dactylus. The ambulatory appendages are long, setose, and spinose except the dactylus joint. A spine over the eye. Antennæ shorter than the body ; a spine on the outer side of the first segment, one on each side of the second and third segments, and one on the upper side of the third segment.

Length of ovigerous female, 47 mm. ; length of carapace, 25 mm. ; breadth, 15 mm. ; rostrum, 8 mm.

Station 3417.	493 fathoms.		1 male, 2 females ovig.
" 3424.	676	"	4 females (2 ovig.).
" 3425.	680	"	7 males, 5 females (2 ovig.).

Munidopsis sericea, sp. nov.

The whole surface of the body and limbs is covered with a silky pubescence. The rostrum is long, curved gently upward, convex above, but not carinated, armed with a prominent spine on each side near the middle, and with three more minute spinules near the base. Gastric region swollen, armed with two conical spines and ten or twelve small spinuloid tubercles. The cardiac region has a prominent transverse ridge near the centre, in front of which is a deep depression separating it from the gastric region; the ridge is armed with a pair of short spinules. There is a small spine on the anterior border between the eye and the antenna, a large one at the antero-external angle, three on the border of each hepatic region (the middle of one of these is the largest), and one small one on the border of each branchial region just behind the cervical suture; there are besides about ten sharp tubercles on each branchial area, and five or six pairs of spinules on the posterior margin of the carapace. Pterygostomian regions granulated. There is a pair of spines on the second, third, and fourth abdominal segments; besides these there are several small spinules on the terga and pleuræ of these segments; the pleuræ are rather narrow, with rounded lateral angles. The chelipeds are wanting in the unique specimen. The ambulatory appendages are spinulose, the spinules of the dactyli restricted to the hind margin. The eye is provided with a very minute spine. The antennæ are rather longer than the body, the basal joint has a short external spine, a longer one at the lower internal angle, and a small one at a higher level on the inner side. The latter spine shows, when the animal is viewed from above, between the eyestalk and the antenna. The subsequent segments of the antenna are armed as usual in this genus.

Length, 39 mm.; length of carapace, 12 mm.; length of rostrum, 8 mm; breadth of carapace, 12 mm.

Station 3394. 511 fathoms. 1 male.

Munidopsis margarita, sp. nov.

In this species the rostrum has a gentle upward curve near the tip; it is carinate above, and minutely spinulous on the margins. The surface of the carapace is rough with squamous tubercles and forward-pointed spines. The gastric and cardiac regions are prominent, and separated from one another by a deep depression; a pair of spines on the gastric, and one spine on the cardiac region, attain a special prominence. A long sharp spine outside the eye forms the outer wall of a well marked orbit. There are eight spines on each lateral margin, six on the posterior (including those at the postero-lateral angles) The branchial areas are iridescent. Second abdominal segment: the anterior transverse ridge, which is broken down in the centre, bears on each side a prominent hooked spine, which is enlarged at the base and denticulated on the outer margin; the posterior ridge is furnished with three hooked spines; the

pleuræ of this segment bear each a broad, flattened, forward-pointing tooth with denticulated edges; when the animal is viewed from above, this tooth appears to form the lateral extremity of the pleura, which really lies below it, and is rounded. Third abdominal segment: both ridges are spiny and denticulate, three spines being specially prominent on each ridge. Fourth abdominal segment: armed with but one small median spinule. The sides of the carapace below the epimeral sutures are covered with spiny tubercles, and display an iridescent lustre. The eye has two spines projecting over the cornea from the inner side; the posterior of these spines is very minute. The antennæ are very slender and about as long as the carapace; the first and second joints are provided with a prominent external spine, the third joint with three spines, viz. one external, one internal, and one superior. The chelipeds are absent in both the specimens. The ambulatory appendages are spinulose on all the segments except the dactyli, which are finely serrate on the hind margin. The legs, and more especially the sternum, are iridescent, like mother of pearl. This iridescence is seen in a less degree in several other species of this genus.

Length, 20 mm.; length of carapace, 11 mm.; breadth, 7 mm.; length of rostrum, 3.5 mm.

Station 3404. 385 fathoms. 1 male, 1 female.

Munidopsis crinita, sp. nov.

The whole surface is clothed with long setæ, which are longest and densest on the chelipeds and ambulatory appendages. The rostrum is very broad at the base and ends in three points, the middle of which is the longest; the rostrum is slightly carinate in the median line. The carapace is roughened by low setiferous ridges. The antero-lateral angles are obliquely truncate; a spine over the antennæ, and four on the lateral margin, the last one just behind the cervical suture, the third one obsolescent; hind margin unarmed. A pair of spines on the gastric region, behind the base of the rostrum. The abdomen is devoid of spines, and there is no spine over the eye. The antennæ are slender, shorter than the body; the basal joint is provided with a long spine on the external side, and another on the internal side; the second joint has an external spine, the third an internal one. Chelipeds: merus five-spined; carpus with one prominent spine; hand unarmed, broadest at base of fingers, cutting edges of fingers toothed. Ambulatory limbs setose, hind border of dactyli spinulose.

Length, 19.5 mm.; carapace, 11.5 mm.; rostrum, 2.6 mm.; breadth of carapace, 7.5 mm.

Station 3384. 458 fathoms. 1 female.

This species resembles *M. rosacea* (A. M. Edw.), *M. latifrons* (A. M. Edw.), and *M. tridens* (A. M. Edw.). From the first (*Comptes Rendus*, XCIII. 934, figured in *Recueil de Figures de Crustacés nouv. ou peu connus*, 1re livr.) it differs in having a much shorter rostrum, in the presence of a pair of spines on the gastric region, in the different shape of the hand, the absence of prominent

spines on the meri of the ambulatory legs, and its greater pilosity. From the second (judging from Milne Edwards's short description of that species) it is distinguished by the long setæ, gastric spines, and broader carapace. From the last it differs in being very hairy, etc. *M. rosacea* comes from the north coast of Spain, *M. latifrons* from the Barbadoes, *M. tridens* from St. Kitts.

Munidopsis ornata, sp. nov.

Carapace convex, the whole upper surface, including the rostrum, thickly covered with low squamous tubercles; seen under a magnifying power the surface of each tubercle is seen to be made up of a number of secondary scale-like prominences; the tubercles are not lengthened out transversely to form ridges on any part of the surface; two of the tubercles on the gastric region take on a spiny character. The rostrum is nearly horizontal, triangular in cross-section, the margins serrate; the anterior border of the carapace is convex between the eyes and the antennæ, but has no spine at this point; lateral border four-toothed, one of the teeth lying at the antero-lateral angle, two on the hepatic region, and one on the edge of the branchial region behind the cervical suture; the posterior border is delicately festooned, but not armed with spines. The abdomen is spineless, its surface punctate, anterior half of the pleuræ of the second segment tuberculate, all the pleuræ rounded. The eye has a transverse granulated tubercle running over the cornea from the inner side. The antennæ are very slender, and do not exceed the carapace in length. The chelipeds are moderately robust; the merus tuberculate and armed with a row of short spines along the upper edge; the carpus spino-tuberculate, with two longitudinal furrows on the outer side; the hand almost smooth on the inner side, outer side and superior surface roughened with low tubercles; fingers a little curved upward, spoon-shaped at the denticulate and setose tips. Ambulatory appendages: meri flattened, tuberculate, upper edge produced to a spinose carina; the carpi have three denticulate ridges; propodi scabrous, with an irregular row of spines on under side; the dactyli have black tips, and are finely spinulose on their posterior edges.

Length, 23 mm.; length of carapace, 12 mm.; breadth, 8 mm.; length of rostrum, 3 mm.

Station 3404. 385 fathoms. 1 male.

Munidopsis scabra, sp. nov.

The rostrum is triangular, slightly curved upward, carinated above, the lateral edges and the carina lightly denticulated. The carapace is covered with squamous setiferous tubercles which end in spiny points. There is a transverse row of six more prominent spiny tubercles on the gastric region. The posterior border of the carapace is ornamented with a denticulated rim (about eight denticles). There is a spine between the eye and the antenna

below the anterior margin of the carapace. The abdomen is devoid of spines, the pleuræ have truncated lateral angles. A spine projects over the cornea of the eye. The antennæ are shorter than the body; a spine on the outer side of the basal joint, one on each side of the second joint, and one on each side and one on superior margin of third joint. The chelipeds are long, spinose, except the fingers; hand long, the basal part longer than the fingers. All the joints of the ambulatory appendages are spiny except the dactyli.

Length (ovigerous female), 40 mm.; length of carapace, 13.5 mm.; breadth, 14 mm.; rostrum, 5 mm.

Station 3424. 676 fathoms. 2 males, 1 female ovig.
" 3425. 680 " 1 male, 1 female ovig.

Munidopsis tanneri, sp. nov.

Carapace flat, quadrangular, covered with squamous setiferous tubercles which have a tendency to develop spiny points on the gastric region. This is especially true of a transverse row of six on the anterior part of that region. The rostrum is triangular and horizontal. There is a prominent spine on each side of the anterior margin of the carapace between the eye and the antenna, another at the antero-lateral angle, and two or three on the side of the hepatic area; the hind border of the carapace is denticulated. A small spine over the eye. Antennæ shorter than the body; one spine on the outer side of the first joint, two lateral and one superior on the second and third joints. Cheliped (present in only one specimen) long, slender; merus and carpus many-spined; propodus spiny along the upper and lower margins; tips of fingers enlarged and denticulated. Ambulatory limbs: a prominent row of spines on the upper edge of the merus and carpus, propodus and dactylus devoid of spines. Abdomen without spines; pleuræ narrow, angles rounded.

Length, 41 mm.; length of carapace, 23.5 mm.; breadth, 15.5 mm.; rostrum, 6 mm.

Station 3396. 259 fathoms. 2 males, 1 female (1 male with *Bopyrus*).
" 3397. 85 " 1 male.

This species is nearly related to *M. scabrosa*, but differs from the latter species in having the carapace broader and flatter, with squamous tubercles which are not produced into points except a few on the gastric area. The spine between the eye and the antenna is longer; the propodi of the ambulatory legs are smoother, with no well-developed spines.

Munidopsis hamata, sp. nov.

Body and limbs clothed with short, scattered setæ. Rostrum long, curved slightly upward, basal half furrowed longitudinally, with a row of short spines on each side of the furrow; infero-lateral edges of rostrum also furnished with small spines. Carapace quadrangular, anterior border forming a right angle with lateral border, both borders spinulose; lateral border with an indentation

at anterior boundary of hepatic area; a deep depression back of each hepatic area and another across the anterior part of the cardiac region; the upper surface of the carapace is adorned with spinulose tubercles, and a median longitudinal row of more prominent spines runs along the gastric and cardiac regions; the anterior spine of the cardiac region overhangs the transverse depression, the posterior spine of the row springs from the hinder rim of the carapace. There is a median hooked spine on the tergum of the second, third, fourth, and fifth abdominal segments and many spiny tubercles irregularly disposed on these segments; the pleuræ of the third to the sixth abdominal segments are narrow but blunt, those of the second to the fifth are costate. The ocular peduncle is movable and devoid of a spine. The antennæ are about as long as the body; the basal joint has an inferior and a small external spine; the second joint also bears an external spine. The chelipeds are long and slender; all the joints from the ischium to the propodus are equipped with longitudinal rows of small spines; the chela is not broader than the basal part of the propodus, the fingers are straight, their prehensile edges denticulate. The ambulatory appendages are spinulose.

Length of male, 49 mm.; length of carapace, 25 mm.; breadth of carapace, 14 mm.; length of rostrum, 9 mm.; length of cheliped, 47.5 mm.; merus, 15 mm.; carpus, 5.5 mm.; chela, 19 mm.

Station	3394.	511 fathoms.		13 males, 16 females ovig.
"	3395.	730	"	3 males.

Munidopsis aspera (Hend.).

Elasmonotus asper Hend., Ann. Mag. Nat. Hist., 5th ser., XVI. 416, 1885; Rep Challenger Anomura, p. 163, Plate XIX. Fig. 4, 1888.

Station	3357.	782 fathoms.		1 female ovig.
"	3358.	555	"	1 male.
"	3370.	134	"	1 female.
"	3402.	421	"	2 males, 5 females (3 ovig.).
"	3403.	384	"	1 male.
"	3406.	551	"	2 males.

This species is subject to considerable variation. In the specimens from Stations 3402, 3403, and 3406 the tubercles of the carapace are more numerous and less spiny than in those secured at the other stations. The ambulatory appendages of all the "Albatross" examples are apparently more spiny than in the types from the "Challenger." The latter came from the Straits of Magellan, 245 fathoms.

Munidopsis quadrata, sp. nov.

Carapace quadrangular, the anterior and lateral margins forming a right angle, upper surface flat, spineless, but furnished with low squamiform tubercles

Rostrum curved upward, broad at base, narrowing anteriorly to form a long, sharp acumen. Central part of gastric region prominent above the hepatic region, from which it is separated by a deep pit. A prominent transverse ridge on cardiac region, forming the posterior wall of a deep fossa. Antero-lateral angles rounded. Second segment of abdomen armed with a median spine which is curved forward; third and fourth segments with a very prominent ridge which bears an acute median tooth; pleuræ of second segment faintly tuberculate, the others narrow with the external angles rounded but not truncate. Eye spineless, almost concealed by the base of the rostrum. Antennæ about as long as the carapace; a conspicuous spine on the upper side of the third segment. Cheliped long, tuberculate with the exception of the fingers; chela slender, fingers not gaping. Ambulatory legs tuberculate with the exception of the dactyli, which are furnished with small teeth on the posterior margin.

Length of body, 29 mm.; length of carapace, 15.5 mm.; breadth of carapace, 9 mm.; length of rostrum, 6 mm.; length of cheliped, 30 mm.

There is some variation in the length and upward curvature of the rostrum among the different specimens. A female, from station 3424, differs markedly from the males in having the tubercles on the carapace and appendages much more strongly developed.

Station 3424. 676 fathoms. 2 males, 1 female ovig.
" 3425. 680 " 1 male.

Munidopsis depressa, sp. nov.

Closely allied to *M. hamata*, but differs as follows. The cephalothorax is more swollen, so that the sides of the carapace are visible below the epimeral sutures when the animal is viewed from above. The median row of spines on the carapace consists of a smaller number of spines (two on the gastric region, one on the cardiac region, and one on the posterior margin). The spinules of the lateral margin of the carapace are less developed. The depression on the carapace involves the gastric region to a greater degree. The anterior margin of the carapace is not so straight, and it is not spinuliferous. The antero-lateral spine is more prominent, the eyes smaller, and the antennæ shorter (shorter than the carapace). There is, moreover, no spine on the fifth abdominal segment.

Length, 32 mm.; carapace, 19 mm.; rostrum, 5 mm.; breadth of carapace, 12.5 mm.

Station 3425. 680 fathoms. 1 male.

Munidopsis carinipes, sp. nov.

Carapace quadrangular, flat, marked by a median tuberculated ridge on the gastric and cardiac regions; sides converging a little from front backward; the antero-lateral angles form a rounded shoulder. Rostrum broad at base, nearly horizontal, sides converging near tip, which is blunt; upper surface nearly

flat, lightly granulated. The rest of the upper surface of the carapace has a coarser granulation. There is a conspicuous hooked tooth on the third and the fourth abdominal segment, and in some specimens there is a rudimentary one on the second and the fifth segment; the teeth on the third and fourth segments have denticulated margins in adult specimens; abdominal pleuræ long and narrow. Chelipeds very long, lightly tuberculate; chela long, slender, fingers rather short, smooth, with straight denticulated prehensile margins. The meri of the ambulatory legs granulated, superior border produced to a keel, the edge of which is entire; the lower margin of the meri is also entire; the carpi have three tuberculated ridges, one superior, two external; the propodi are lightly tuberculated; dactyli smooth, their hind margin armed with about five teeth. Eye spineless, nearly hidden under the rostrum. Antennæ shorter than the carapace, first, third, and fourth joints armed with an external spine.

Length, 30 mm.; carapace, 16 mm.; breadth, 9.5 mm.; rostrum, 5 mm.; cheliped, 40 mm.; merus, 13 mm.; carpus, 4.5 mm.; propodus, 17 mm.; dactylus, 7 mm.

Station 3353. 695 fathoms. 2 males, 1 female ovig.

Near *M. longimana* (*Elasmonotus longimanus* A. M. Edw.), from which it differs in having the rostrum more nearly plane, the merus of the cheliped much less strongly tuberculated, the meri of the ambulatory limbs more strongly carinated, with lower margin entire instead of denticulate; the spine on antennal peduncle is more prominent, while the tooth on the second segment of the abdomen is absent or at best rudimentary.

Two specimens (male) of *Elasmonotus longimanus* A. M. Edw., and one (female) *E. brevimanus* A. M. Edw., have been returned to Cambridge from Paris. I suspect that these may prove to be the male and female of one species. The chelipeds of the female specimen of *M. cristatipes* are lost.

Munidopsis hendersoniana, sp. nov.

In this species, as in *M. armata* (*Elasmonotus armatus* A. M. Edw.) and *M. marginata* (*Elasmonotus marginatus* Hend.), the lateral margins of the carapace are extended as sharp crests overhanging the sides of the body. The upper surface of the carapace is rather flat, and is clothed with a close short pubescence; the sides are nearly parallel. The rostrum is long, acute, nearly horizontal, the upper surface roof-shaped. There is an acute tooth on the anterior margin of the carapace external to the eyestalk and another at the antero-lateral angle; otherwise the carapace is unarmed. The eyestalks are immovable and prolonged into a long horn one half as long as the rostrum, seen from above, the eyestalks appear like lateral spines of the rostrum. The eye is rudimentary, occupying the basal part of the lower side of the peduncle. The antennæ are shorter than the body, the basal joint armed with a well developed inferior spine. The chelipeds are short robust and tomen-

tose; there is a spine at the distal superior angle of the ischium and another near the distal end of the lower internal edge; five spines along the superior margin of the merus and two inferior distal spines; the carpus bears a superior proximal tooth together with three teeth on the distal margin; the chela is short and stout, the hand without teeth or spines; the fingers are very thick and short, meeting one another only at their spoon-shaped denticulated tips; there is a rounded tubercle at the base of the inner margin of the immovable finger; the outer margin of this finger is denticulated. Ambulatory limbs: five to seven spines on the superior and external inferior margins of the meri (those on the superior margin the largest); upper edge of carpus three- to four-spined; propodi and dactyli unarmed. Abdomen without spines.

Length, 37 mm.; carapace, 20 mm.; rostrum, 6.5 mm.; breadth of carapace, 12 mm.; length of cheliped, 28 mm.

Station 3393. 1020 fathoms. 3 males, 1 female (with *Peltogaster*).

Nearly related to *M. edwardsii* (*Elasmonotus edwardsii* Wood-Mason, Ann. Mag. Nat. Hist., 6th series, VII. 201, 1891) of the Bay of Bengal, but easily distinguished from that species by the lateral margins of the carapace, which in Wood-Mason's species are divided into two lobes, but in *M. hendersoniana* are entire.

Munidopsis inermis, sp. nov.

In this species the whole surface of the body and appendages is naked and free from spines and tubercles. The carapace is rather flat above, with subparallel sides; the gastric region is protuberant and separated from the hepatic and cardiac areas by conspicuous furrows. The surface of the carapace is punctate and lightly granulate and rugose on the branchial regions. The rostrum is triangular, blunt at the apex, bent strongly downward, and slightly carinate above. The antero-lateral angle is rounded, and a rounded lobe projects from the anterior margin above the base of the antenna. The abdomen is smooth, naked, devoid of spines and ridges; the abdominal pleuræ are rounded. Ocular peduncle free, spineless. The peduncle of the antenna is also destitute of spines; the flagellum is wanting in the only specimen obtained. The chelipeds are also missing. The ambulatory appendages are smooth, unarmed; the dactyli long (equal to the propodi in length), slightly curved, acute at the tips. The appendages of the third, fourth, and fifth abdominal segments are simple and rudimentary. The merus of the third maxilliped is short, its antero-internal margin three-toothed; the palpus of this appendage is nearly as long as the merus and ischium combined.

Length, 12 mm.; carapace, 6 mm.; breadth, 4 mm.

Station 3354. 322 fathoms. 1 male.

This species nearly resembles *M. polita* (*Anoplonotus politus* Smith), but the carapace of the former is longer and narrower, the rostrum is curved more strongly downward, and the propodi of the ambulatory limbs are much shorter in proportion to the dactyli.

Uroptychus nitidus occidentalis, subsp. nov.

Differs from the typical *Uroptychus nitidus* (A. M. Edw.)[1] as follows: the branchial regions are more swollen, giving to the posterior half of the carapace a more convex lateral outline; the rostrum is shorter, the chelipeds shorter and more robust, the fingers shorter in proportion to the length of the basal part of the propodus; the branchial regions are more distinctly margined. It approaches in some respects *U. uncifer* (A. M. Edw.), in which the rostrum and chelipeds are still shorter. In some specimens of *occidentalis* there are a few low tubercles on the inner side of the proximal end of the merus and ischium of the chelipeds, — a condition similar to that in *U. australis* Hend. which may be considered a variety of *U. nitidus*. *U. politus* Hend., another closely related form, is distinguished by its short antennal acicle.

Length of body of a female, 29 mm.; length of carapace, 15 mm.; length of rostrum, 4 mm.; breadth of carapace between antero-lateral spines, 5 mm.; breadth across the branchial region, 10 mm.; length of cheliped, 44.5 mm.; merus, 11 mm.; carpus, 12.5 mm.; chela, 17.5 mm.; dactylus, 6 mm.

Station 3384. 458 fathoms. 2 males, 2 females ovig.

Uroptychus pubescens, sp. nov.

Carapace, without including rostrum, broader than long, pubescent; a transverse row of spines across the gastric region from one side of the carapace to the other; lateral border of carapace spinulose; the anterior margin has a deep concavity above the eye, outer angle of the concavity armed with a spine. Rostrum one half as long as the rest of the carapace, bent downward a little, acute, with entire setiferous margins. Eye small, not broader than the eye-stalk, with brown pigment. Abdomen naked, smooth, pleuræ subacute. Antennæ equal in length to the carapace with the rostrum; acicle shorter than the peduncle. Chelipeds long, all the joints as far as the fingers spinulose, the spinules with broad bases; propodus not broader than the carpus; carpus equal in length to the basal portion of the propodus; fingers straight, a slight tooth near the base of the dactylus; the tips of the fingers cross. Meri of ambulatory legs minutely spinulose on the superior margin, distal end of propodus spiniform on the hind margin, whole hind margin of dactylus armed with spines; all the joints of the ambulatory limbs are furnished with long setæ.

Length (female), 44 mm.; breadth, 17.5 mm.; length of carapace, 21 mm.; length of rostrum, 7.5 mm.; length of cheliped, 57 mm.; merus, 12 mm.; carpus, 15 mm.; chela, 24 mm; dactylus, 9.3 mm.

Station 3354. 322 fathoms. 2 females ovig.
" 3355. 182 " 1 female ovig.

This species is more nearly related to *U. insignis* Hend. than to any other described species.

[1] Bull. Mus. Comp. Zool., VIII. 62, 1880.

Uroptychus bellus, sp. nov.

Carapace broad, branchial regions inflated, upper surface naked, smooth, and polished; the branchio-cardiac lines meet in the median line of the carapace; the anterior margin has a concavity above the eye, forming an orbit with a spinule at its external angle. There is one spine at the antero-lateral angle, one on the margin of the hepatic area, and eight on the margin of the branchial region; the branchial spines decrease in size posteriorly. The rostrum is long, tapering, acute at the apex, and concave at the base above. The abdomen is smooth, the pleuræ subacute. The eyestalks are short and stout, the eye not wider than the peduncle, black. The antennæ are very slender, shorter than the carapace, the acicle considerably shorter than the peduncle. Chelipeds very long, naked except for a few setæ on the fingers, polished; the ischium bears a spine on the superior margin and several others on the lower side; the merus and carpus are armed with spines arranged in longitudinal rows; there is a row of spines on the upper margin of the propodus (the row is double at the proximal end), another series on the outer face reaching from the proximal end about half-way to the distal end, and another still shorter row of more rudimentary spines just outside the latter series; the fingers are separated by a gap; their prehensile edges are denticulate, with one or more prominent teeth near the base of the dactylus. Ambulatory appendages: meri and carpi of the first and second pairs spinulose along the upper edge, these joints being spineless on the third pair. All of the ambulatory appendages are subchelate, the distal end of the propodus being enlarged and furnished with spines against which the spined dactylus closes.

Length (male), 17 mm.; carapace, 10.5 mm.; rostrum, 4.5 mm.; breadth of carapace, 7.7 mm.; cheliped, 31 mm.; merus, 7 mm.; carpus, 9 mm.; chela, 14 mm.; dactylus, 5 mm.

Station 3354. 322 fathoms. 1 female ovig.
" 3355. 182 " 1 male.

Family AXIIDÆ.

Axius crista-galli, sp. nov.

Near *Axius acutifrons* (*Eiconaxius acutifrons* Bate), but differs in the following regards. The margin of the rostrum is armed with prominent teeth. The median carina of the rostrum, entire or at most but slightly serrate in the former species, is here cut into about seven prominent teeth. The larger claw differs from the corresponding organ in *A. acutifrons* in lacking the serration on the superior margin of the propodus, in the presence of a strong tubercle on the anterior border of the hand between the bases of the fingers, and in the absence of prominent teeth on the prehensile edges of the fingers.

Length, 24.5 mm.; length of carapace, 10 mm.

Station 3359. 465 fathoms. 3 males, 1 female.

The female carries eighteen eggs of large size (2 × 1.5 mm.).

Family CALOCARIDÆ.

CALASTACUS, gen. nov.

Abdomen long, enlarged in the middle, narrowed at each extremity, pleura broad and rounded. Cephalothorax laterally compressed, rostrum long, acute. eyes rudimentary, subglobose, unpigmented, unfaceted. Second antenna on a horizontal line with the first antenna; the second segment armed with a long external spine (stylocerite) and a still longer articulated style-shaped scale (scaphocerite). Third maxilliped pediform. First and second pairs of legs chelate. First abdominal appendages of male modified to serve as sexual organs (gonopods). Outer branch of swimmerets divided near the posterior margin by a diagonal suture. Telson long, quadrangular. Gills composed of a central stem which bears two rows of filaments. Branchial formula:

Somite	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.		
Epipods	1	1	1	1	1	1	0	=	6
Podobranchiæ . .	0	1	1	1	1	0	0	=	4
Arthrobranchiæ .	0	2	2	2	2	2	0	=	10
Pleurobranchiæ .	0	0	0	0	0	0	0	=	0

Differs from *Calocaris* in having a long styloid scaphocerite appended to the peduncle of the external antennæ.

Calastacus stilirostris, sp. nov.

Carapace naked, punctate; apex of rostrum turned a little upward; two strong spines turned upward and forward at base of rostrum; a light median carina runs along the back from the base of the rostrum, fading out before reaching the hind border of the carapace. Chelipeds long, symmetrical on the two sides; coxa furnished with a small spine on the anterior border of the distal end; ischium armed with from one to four spines on the lower margin; merus laterally compressed, armed with a spine on the upper edge near the distal end and a variable number (four to eight) of spines on the lower edge. Carpus triangular, unarmed. Chela: upper and lower margins sharp, the upper armed with five to seven spines, inner and outer faces with a few scattered spinules; fingers with denticulate prehensile edges and curved crossed extremities. Second pair of legs furnished with small chelæ.

Length of carapace, 22.2 mm.; rostrum, 5.5 mm.; abdomen, 30 mm.; chelipeds, 39 mm.; chela, 17 mm.

Station 3418. 660 fathoms. 9 males.

Family ASTACIDÆ.

Nephropsis occidentalis, sp. nov.

Pubescent. Carapace cylindrical, the branchial regions convex. Rostrum densely ciliated on the margins, armed with a pair of lateral teeth near the middle; a double row of prominent granulations on the dorsal surface, diverging posteriorly and continued backward for some distance on the gastric region. A small, blunt papilla in the median line of the gastric area, a pair of acute teeth near the anterior margin at the base of the rostrum, and another pair just above the insertion of the second pair of antennæ; a small papilla in the median line on the intestinal region. Abdominal pleuræ rather longer-pointed than in *N. stewarti*, but not so much so as in *N. agassizii* and *N. atlantica;* their anterior borders are finely denticulated, but are destitute of spinous processes. Telson armed with a sharp spine in the median dorsal line, near the proximal end.

Length, 119 mm.; carapace, 51 mm.; rostrum, 14 mm.; second antenna, 225 mm.

Station 3418.	660 fathoms.	23 males, 32 females.
" 3424.	676 "	2 males.

Family ERYONTIDÆ.

Willemoesia inornata, sp. nov.

Similar to *W. leptodactyla*, but readily distinguished from it by the small number of spines on the margin and dorsal ridges of the carapace. The armature may be formulated thus: —

Marginal	5 to 8 — 2 to 3 — 0 to 6
Median ridge	1 to 5 — 0

The marginal spines which lie behind the cervical groove, if found at all, are but rudimentary, while there are no spines on the submarginal carina or along the lateral boundaries of the cardiac area, where they are present in *W. leptodactyla*. The third maxilliped bears only a slender epipod; the membrane that connects this limb with the body carries a small, but perfectly formed gill (arthrobranchia). According to Spence Bate, this gill is absent in *W. leptodactyla*.

Station 3374.	1823 fathoms.	8 males, 6 females.
" 3381.	1772 "	1 male, 1 female ovig.
" 3382.	1793 "	2 males, 4 females (1 ovig.).
" 3399.	1740 "	2 males, 1 female.
" 3400.	1322 "	1 female.

Polycheles[1] tanneri, sp. nov.

Orbital sinus rounded at the bottom, outer margin spinulose. Median carina of carapace furnished with two anterior rostral spines, followed by five (or six) spines in front of the cervical groove, the fourth (or fifth) of which is double. The arrangement of these spines may be thus formulated: 2. 1. 1. 1. 1. 2. 1 (or, 2. 1. 1. 1. 2. 1). Back of the cervical groove the spines of the median carina are 2. 2. 2. Marginal spines of carapace arranged as follows: 5—3—13 or 14). A longitudinal row of four small spinules on the anterior division of the carapace midway between the median and marginal rows, and a row of twelve or fifteen on the branchial regions inside the margin of the carapace. There are, besides, two or three spines on each side of the hind margin of the carapace, and a few along the cervical groove.

Resembles *P. nanus* (Smith), but differs in the number of spines on the median and sublateral carinæ of the carapace, in the existence of a spine on the antero-external angle of the first and second abdominal pleuræ, and in the greater number of spines on the merus, carpus, and propodus of the chelipeds. *P. nanus*, moreover, is described as having the posterior pair of thoracic appendages chelate in the male, while in the males of *P. tanneri* that I have examined these appendages are simple. Compared with the types of *P. agassizii* (A. M. Edw.), the carapace of the present species is broader and fewer-spined on the margins; the first and second abdominal pleuræ are armed with an anterior lateral spine; the rostral spine is double; and the orbital sinus is broad and rounded at the bottom. *P. agassizii*, like *P. tanneri*, has non-chelate posterior legs in the male.

Station	3354.	322	fathoms.	1 male.
"	3402.	421	"	2 males, 1 female.
"	3403.	384	"	12 males, 14 females.
"	3409.	327	"	1 female.

Polycheles sculptus pacificus, subsp. nov.

Differs from the Atlantic *P. sculptus* Smith as follows. The carapace is broader in proportion to the breadth of the abdomen, the lateral margins converging strongly at the posterior end, where, in *P. sculptus*, they continue nearly parallel to one another; there is a small spine on each branchial region inside of and on a level with the second spine of the submarginal carina, which spine is entirely wanting in *P. sculptus*; the spine on the anterior border of the ophthalmic lobe is larger and blunter; the pleuræ of the second abdominal somite have a different shape, their anterior margins being in line with the anterior margin of the tergum, whereas in *P. sculptus* they form a strong obtuse angle with that margin.

[1] The genus *Polycheles*, as here defined, comprehends *Polycheles*, *Pentacheles*, and *Stereomastis* of Bate.

These differences, although slight, are constant, and should be recognized in our nomenclature, if any significance is attached to geographical variation.

The last thoracic appendages are chelate in the adult female, while they are but imperfectly so in breeding males; that is, in the male the "thumb" is very much shorter than the index.

Station	3353.	695	fathoms.	1 male.
"	3392.	1270	"	1 female.
"	3393.	1020	"	3 males, 3 females.
"	3394.	511	"	12 males, 20 females.
"	3418.	660	"	1 male, 1 female.
"	3419.	772	"	1 female.
"	3424.	676	"	1 female ovig.

Polycheles granulatus, sp. nov.

Carapace long oval, broadest across the anterior branchial region; dorsal surface granulated, but nearly devoid of spines; there are two small rostral spines, and back of these, on the low granulated median carina, lies another pair followed by one or two spinules on the gastric area. The submarginal ridge is incurved and composed of minute spinulose granules. Orbital notch narrow, armed with a spine at its internal angle and with another at its external angle. Marginal spines thus disposed: 9 (or 10) — 3 — 15. The anterior abdominal pleuræ are rounded, gradually becoming acute as one passes backward to the sixth. The posterior thoracic legs in the sole specimen seen (a female) end in a small but perfect chela.

Length, 99.5 mm.; length of carapace, 45 mm.; greatest width of carapace 37 mm.; length of cheliped, 118 mm.; ischium, 19 mm.; merus, 33 mm.; carpus, 22 mm.; basal part of propodus, 14.5 mm.; dactylus, 22 mm.

Station 3380. 899 fathoms. 1 female.

Eryonicus cæcus Bate?

Station	3375.	1201	fathoms.	1 male, 62.5 mm. long.
"	3377.	764	"	1 female, 40 mm. long.
"	3383.	1832	"	1 juv., 37 mm. long.
"	3388.	Surface to 400 fathoms, submarine tow-net.		4 juv., 19–29 mm. long.

Bate's description of *E. cæcus* was drawn up from a single immature specimen, 13 mm. long, in which the first abdominal appendages were undeveloped. The largest of the "Albatross" specimens is a sexually mature male with well developed gonopods. It differs from Bate's specimen in having much shorter spines upon the carapace and abdomen; the spines of the lowest series on the branchial region decrease in length posteriorly, while in the type spceimen the posterior spines in this row are the longest. Whether these discrepancies are

due to difference in age, or whether they denote specific diversity, cannot be determined until more mature specimens are obtained from the Atlantic. In the smallest of the "Albatross" specimens (which have attained a length of 19 mm.) the spines, especially those of the abdomen, are relatively longer than in the adult, though not so long as in the type described by Bate.

As regards the ophthalmic sinuses and lobes, the genus *Eryonicus* is like *Polycheles* (*Pentacheles*).

Eryonicus spinulosus, sp. nov.

In this species the spines of the carapace, instead of being wellnigh limited to nine longitudinal ridges, as in *E. cæcus*, are thickly strewn over the whole surface. The intervals between the spines give rise to slender hair-like setæ. This is the arrangement of the spines of the median carina of the carapace:

2. 1. 1. 1. 2. 1. 1. — 2. 2. 1. 2.

The sublateral carina bears fourteen small spines, the lateral,

5 — 2 — 13 or 14.

The uppermost of the two carinæ below the lateral is denticulated anteriorly and armed with a spine at the front end behind the second antenna. The lowest ridge carries twelve spines, which increase slightly in length posteriorly. The rostral spines are very small, but on each side of the rostrum the front margin of the carapace is produced so as to form a pair of horns over the base of the first pair of antennæ. The abdomen is ornamented with seven longitudinal rows of spines, one dorsal and median, the others paired and lateral. The lowest of the lateral rows is on the upper part of the pleuræ.

Length, 37 mm.; carapace, 21 × 17 mm.; abdomen, 17 mm.

Station 3403. 384 fathoms. 1 specimen.

Family GNATHOPHYLLIDÆ

Gnathophyllum panamense, sp. nov.

Closely related to *G. elegans* of the Mediterranean Sea, but distinguished by a prominent conical protuberance, pigmented with black, on the upper part of the cornea. In *G. elegans* this tubercle is wanting or reduced to the merest vestige, discernible only by aid of a lens. The rostrum of *G. panamense* is furnished with seven teeth above, and one below. Color entirely different from that of *G. elegans*. The ground tint is dark brown, ornamented with a multitude of light blue spots, amongst which are sixteen red spots. Rostrum, eyes, and antennæ whitish, flagellum of second antenna orange. The fifth and sixth abdominal segments, the telson, and the swimmerets are also white. Basal joints of second pair of chelipeds violet, the merus, carpus, and fingers whitish, basal part of propodus orange. Third, fourth, and fifth pairs of legs violet.

Panama, March 12. 1 female ovig.

G. pavimatum Stimpson, from Australia and Amboyna, agrees closely in

form with *G. elegans*, but differs wholly in the pattern of its color marks from both *G. elegans* and *G. panamense*. *G. zebra* Richters, from Mauritius, is without much doubt the same as *G. fasciolatum*. Ortmann has lately recorded a *Gnathophyllum* from Tahiti as a new species, *G. pallidum*. It differs from *G. fasciolatum* only in the absence of color marks, — a difference due possibly to the action of alcohol.

Family CRANGONIDÆ.

Sclerocrangon atrox, sp. nov.

Of the described species of *Sclerocrangon*, *S. ferox* G. O. Sars comes nearest to this species. These are some of the chief points of difference. In *S. ferox* the upturned rostrum is simple, while in *S. atrox* a long acute tooth is given off from its ventral side, a tooth which reaches as far forward as the tip of the rostrum. In the former species the dorsal carinæ of the sixth abdominal segment bear two pairs of well developed spines, while in the latter species one finds but one pair of very small spines at the posterior end of the carinæ. The pleural spines of the abdomen are much longer in the former than in the latter, and on the fifth somite there are four to five spines on each pleura against two in *S. atrox*. The eyes are much smaller in *S. ferox*, and lack the spine above the cornea seen in *S. atrox*.

Length of the largest specimen (a female), 162 mm.

Station 3418.	660 fathoms.	3 males, 2 females (1 ovig.).
" 3424.	676 "	4 females.

Sclerocrangon procax, sp. nov.

Nearly related to *S. agassizii* Smith, from the Atlantic side of the continent. The rostrum of *S. procax* is longer than in *S. agassizii*, and inclined upward at a much sharper angle ; the same is true of the antero-lateral spines of the carapace. The most conspicuous difference is found in the anterior spine of the median carina of the carapace, which is much longer and nearly erect in *S. procax*. The two flagella of the first antenna in the male, *S. procax*, are subequal, while in the male *S. agassizii* the outer flagellum is much longer than the inner; the scale of the second antenna, moreover, is narrower in the former species than in the latter, and the terminal segment of the inner branch of the second abdominal appendage in the male bears on its inner margin a short blunt stylamblys, which is wanting in *S. agassizii*. In neither of these species is this segment produced into a lobe at the base of its outer margin, as it is in the more typical species of *Sclerocrangon*, e. g. *S. ferox* and *S. atrox*.

Length, 49 mm.

Station 3380.	899 fathoms.	1 male juv.
" 3418.	660 "	2 males, 3 females.
" 3435.	859 "	2 females ovig.
" 3436.	905 "	1 female.

Pontophilus occidentalis, sp. nov.

Allied to *P. abyssi* Smith and *P. batei*.[1] From the former it differs in having a shorter rostrum, larger eyes, and more strongly developed carinæ on the carapace. From the latter it also differs in its shorter rostrum armed with two pairs of lateral teeth; in the presence of a sharp spine on the sternum between the second pair of legs; in the length of the antennal scale, which in *P. occidentalis* is equal to the distance from the tip of the rostrum to the cardiac spine; in the shortness of the second pair of legs, which reach only half way to the distal end of the merus of the first pair; and in the absence of the spine on the outer margin of the merus of the first pair of legs.

The eyes are as large as in *P. gracilis* Smith(much exceeding the rostrum), but they are nearly colorless, and unfaceted, as in *P. abyssi* and *P. batei*.

Length, 73 mm.; carapace, 21 mm.

Station	3361.	1471	fathoms.	2	specimens.
"	3363.	978	"	2	"
"	3366.	1067	"	1	"
"	3381.	1772	"	4	"
"	3382.	1793	"	5	"
"	3392.	1270	"	1	"
"	3398.	1573	"	2	"
"	3413.	1360	"	4	"
"	3414.	2232	"	1	"
"	3415.	1772	"	2	"

Paracrangon areolata, sp. nov.

Rostrum long, acute, upturned, inferior margin armed with two spines. A prominent carina extends the length of the carapace in the median dorsal line; it is armed with four spines, three on the gastric, one (obsolescent) on the cardiac region. Orbit incomplete, bounded externally by a slender spine. Just below the base of the second antenna the antero-lateral angle of the carapace is drawn out into another rather stronger spine. Just behind this, and from a little higher level, a strong, sharp horn is directed outward and forward; this horn is in continuity with a rounded ridge which runs inward to the external orbital spine. A longitudinal carina on each side of the gastric region, armed with a small spine a little way behind the middle; from this spine another ridge runs upward and inward, meeting the median carina at the base of the third spine. The branchial regions are traversed by a series of ridges which

[1] *Pontophilus gracilis* Bate, Rep. Challenger Macrura, p. 487, 1888. This name having been previously employed for another species by Smith (Bull. Mus. Comp. Zool., X, 26, 1882), I have substituted the name *Pontophilus batei* for *P. gracilis* of Bate.

anastomose in such a way as to divide these regions into cells of different sizes; they are armed with three small spines, the anterior of which is the spina hepatica.

The thoracic sterna are armed with two median spines, one of which is situated on the somite which normally bears the second pair of legs (absent in this genus), the other on the somite behind this. Abdominal pleuræ acute.

Chelipeds of moderate length, with a spine on each side of the distal end of the carpus, and another long and acute one at the antero-internal angle of the propodus.

Length, 85 mm.

Station	3424.	676 fathoms.	2 males, 3 females (1 ovig.).
"	3425.	680 "	1 male.

Family GLYPHOCRANGONIDÆ.

Glyphocrangon alata, sp. nov.

Rostrum armed with a pair of lateral spines on a level with the anterior end of the eye; posterior to this pair of spines follows a variable number of smaller marginal spines (three to five on each side). The anterior half of the rostrum is unarmed, although ciliated on the margin. A light spinulose carina runs along the median line of the rostrum from the base to the anterior third (in some specimens this carina is obsolete). On each side of the median line there are, on the basal part of the rostrum, four or five small spinules.

Carapace and abdomen thickly tuberculated. On the antero-lateral regions of the carapace, and on the abdominal pleuræ, the tubercles assume a spiny character. For the rest, the tubercles are mostly compressed, their tops truncate and more or less eroded. It is further to be noted that these tubercles are arranged in longitudinal rows, and that six of these rows on each side of the carapace form, by their prominence, imperfect carinæ, corresponding in position to those commonly found in species of this genus. Between the external orbital spine and the spine at the antero-lateral angle of the carapace lies a strong spinous tooth, acute at the end and vertically compressed, its base broadening out in such a fashion that the whole tooth forms an acute, wing-like expansion. This is, in fact, the greatly developed anterior part of the fourth carina (counting from the median dorsal line). Behind it the carina continues as a low toothed ridge. A median interrupted dorsal carina runs along the abdomen, broken up into two teeth on the base of the telson.

Length, 116 mm.

Station	?		12+	specimens.
"	3395.	730 fathoms.	1	"
"	3418.	660 "	2	"

Glyphocrangon spinulosa, sp. nov.

Rostrum long, acute, margins armed with vertically flattened spinous teeth from base to the level of the anterior extremity of the eyes, beyond which point the margins are unarmed; the anterior pair of the lateral spines are the largest. A median longitudinal row of smaller spines extends from the anterior boundary of the gastric area to the anterior fourth of the rostrum; anteriorly, these spines are confluent at their bases, forming a carina which is continued forward beyond the spines to the tip of the rostrum. Just inside the marginal spines is an irregular longitudinal row of very small spinules on each side of the rostrum.

The carapace is thickly covered with spinules which are laterally compressed. Along six longitudinal lines on each side of the carapace the spines are larger, more flattened, forming interrupted carinæ. The third carina (reckoning from the dorsal line) ends anteriorly at the deep branchio-hepatic sulcus. The fourth carina is especially prominent on the hepatic region, where it is broken up into two or three prominent teeth. The two lowermost carinæ are obsolescent. The anterior margin of the carapace is produced into a large external orbital spine, directed obliquely upward and outward. The hind margin of this spine is furnished with a variable number of spinules.

The abdomen, like the carapace, is spinulose on the dorsum and pleuræ. An interrupted carina extends the length of the median dorsal line. On the sixth segment this carina is toothed along its edge. The second to the fourth abdominal pleuræ are armed with two spines curved outward and backward, the anterior one being the larger. The fifth pleura is likewise armed with two spines, but in this case the posterior spine is the larger. The sixth pleura ends posteriorly in a single spine directed outward at a greater angle than those of the more anterior somites. The median dorsal abdominal carina is continued along the basal part of the telson as a line of four or five teeth, which decrease in size from before backward.

Length, 105 mm.

Station	3353.	695	fathoms.	11	specimens.
"	3418.	690	"	91	"
"	3419.	772	"	1	"
"	3424.	676	"	19	"
"	3425.	680	"	1	"
"	3435.	859	"	2	"

Glyphocrangon sicarius, sp nov.

Rostrum as long as the rest of the carapace, armed with a pair of short, blunt, lateral teeth, a little in advance of the front of the eyes, and with another pair of obsolescent ones at the root. Between these two pairs of teeth the margins of the rostrum are concave and slightly raised. From the anterior

teeth the rostrum tapers regularly to the point. The upper surface is plane and smooth. A slight median carina, most obvious near the tip, runs through the whole length of the rostrum from the anterior end of the gastric area to the tip; the lateral margins are slightly rimmed. The lower surface of the rostrum is longitudinally grooved, and wholly devoid of a median keel.

Orbital spine rather short and thick, directed a little outward and upward. The spine at the antero-external angle of the carapace is also short and thick, slightly exceeding in length the orbital spine. From its base a low keel extends backward over the hepatic area, — a keel unarmed with spines, but broken into two tubercles, the hinder of which is the more prominent. In the small triangular area between this keel and the gastro-hepatic sulcus are several tubercles disposed for the most part in a single row. The gastric region is free from tubercles in the median line save one minute one at the anterior boundary near the base of the rostrum; but on either side, this region is ornamented with tubercles; these are not spiny, nor do they tend to form very well marked carinæ. On the branchial regions there are three carinæ on each side; the uppermost of these is broken up into five or six tubercles; the top of these tubercles, as well as those of the other carinæ on the branchial and hepatic areas, exhibit a corroded surface, and a similar appearance is manifest on the whole lower surface of the carapace where it is bent beneath the thorax. The abdomen is irregularly bestrewn with low tubercles. The telson is straight and much shorter than the rostrum; it is furnished with a small, laterally compressed tooth in the median dorsal line at base; both the dorsal carinæ and the lateral margins are obsoletely dentate along their basal half.

Length, 124 mm.; length of rostrum from tip to anterior gastric groove, 30.5 mm.; length of carapace, including rostrum, 58 mm.

Station 3382. 1793 fathoms. 2 specimens.

Family PANDALIDÆ.

Heterocarpus vicarius, sp. nov.

This is the Western representative of *H. gibbosus* Bate, from the Philippine Islands. It differs from that species as follows. The carapace is very much longer both in proportion to its height and to the length of the rostrum, and its dorsal margin is not so convex. The teeth on the upper edge of the rostrum are more numerous and closely set. The lateral carinæ of the carapace are more prominent. The third abdominal somite forms a sharper angle or knee. Finally, the antennulary flagella are longer and subequal in length.

Length, 110 mm.; rostrum, 26 mm.; carapace, including rostrum, 55 mm.

Station	3385.	286	fathoms.	49	specimens.
"	3386.	242	"	91	"
"	3389.	210	"	7	"
"	3396.	259	"	68	"

Heterocarpus hostilis, sp. nov.

Similar to *H. alphonsi* Bate, from off the Philippine Islands and Japan, but readily distinguished from that species by the stronger upward curve of the rostrum, by the presence of but one tooth in the median dorsal line of the carapace back of the base of the rostrum, and by the *two* spines on the third abdominal segment.

Length, 197 mm.; rostrum, 70 mm.; carapace, including rostrum, 108 mm.

Station	3353.	695	fathoms.	22	specimens.
"	3363.	978	"	24	"
"	3364.	902	"	3	"
"	3371.	770	"	20+	"
"	3380.	899	"	6	"
"	3393.	1020	"	8	"
"	3395.	730	"	2	"

Heterocarpus affinis, sp. nov.

Very similar to *H. hostilis*, from which it differs in the following particulars. The rostrum is much shorter; measured from the tip to the posterior limit of the orbit, it about equals the rest of the carapace in length. There are fewer teeth on its dorsal margin (five or six); the number of teeth on its lower margin varies from six to ten. The median dorsal line of the carapace is more convex, and it is armed, back of the base of the rostrum, with two acute teeth, where there is but one tooth in *H. hostilis*.

It bears a resemblance, further, to *H. dorsalis* Bate, collected by the "Challenger" in the Banda Sea, but it may be at once distinguished from the Oriental species by its shorter rostrum and the presence of two median teeth on the third abdominal segment.

H. affinis and *H. hostilis* belong to different geographical areas. *H. affinis* is the more northern form, found off Acapulco and Cape Corrientes, while *H. hostilis* was obtained in the Gulf of Panama.

Station	3418	660	fathoms.	13	specimens.
"	3424.	676	"	5	"
"	3425.	680	"	9	"

Family NEMATOCARCINIDÆ

Nematocarcinus agassizii, sp. nov.

The rostrum is one fifth longer than the rest of the carapace (in some small specimens only equal to the rest of the carapace), slender, nearly horizontal for the basal two fifths of its length, the remaining portion gently upturned and ending in a very acute point; its upper margin is continued backward in the

form of a carina, which becomes obsolete on the hinder part of the gastric region; this carina is pectinate, or armed with close-set, forward-pointing teeth on the anterior part of the gastric region; the teeth are continued on the upper margin of the rostrum through one third or two fifths of its length, the distal third or three fifths of the rostrum being entirely free from teeth above; the lower edge of the rostrum is ciliated above the eyes and armed with three (rarely four) teeth, separated by wide intervals, on the distal half.

The third abdominal segment is somewhat prolonged posteriorly over the next segment, but the hind margin is rounded off and does not form a prominent tooth. The telson is tipped with three pairs of spines, the intermediate pair the longest; there are, besides, about six pairs of small spines on the dorsal side of the telson.

The flagella of both the antennules and antennæ are prodigiously developed, the antennule being nearly twice, the antenna more than twice, the length of the whole body including the rostrum; excepting the proximal part of the organ, the annuli of the antennary flagellum are enlarged at the distal end, giving a beaded appearance to the flagellum. The antennal scale reaches rather more than half-way to the end of the rostrum; it is truncate at the distal end and armed externally with an apical spine.

The legs have the characteristic shape and proportions of the genus. The dactyli of the third and fourth pair are slender, acute, somewhat curved, and invested by a pencil of long hairs. The dactyli of the fifth pair are stouter but very short, and hidden in the tuft of hairs which arises from the distal end of the propodus.

The outer blade of the swimmeret slightly surpasses the telson. It is fringed with long hairs along the internal and distal margin, and furnished with a minute tooth and a movably articulated spine on the external border near the distal end. The inner blade is a trifle shorter than the telson; it is also fringed along its whole margin with long hairs.

Dimensions of a female specimen. Length of body, rostrum included, 139 mm.; length of rostrum, 35 mm.; length of carapace, rostrum included, 61 mm.; length of telson, 20 mm.; length of antennule, 267 mm.; length of antenna, 315 mm.; length of antennal scale, 19 mm.

This species, like all the *Nematocarcini*, is very fragile. The long and slender rostrum is often broken off during life, and the attempt to restore it sometimes results in an abnormally small and otherwise monstrous rostrum, which might easily be mistaken for a specific character if ample material were not at hand.

Station	3353.	695	fathoms.	2	specimens.
"	3354.	322	"	4	"
"	3358.	555	"	90	"
"	3359.	465	"	2	"
"	3364.	902	"	4	"
"	3370.	134	"	8	"
"	3380.	899	"	7	"
"	3384.	458	"	1	"

Station	3393.	1020 fathoms.	8 specimens.		
"	3395.	730 "	3	"	
"	3406.	551 "	1	"	
"	3407.	885 "	14	"	(1 bopyrized).
"	3418.	660 "	4	"	
"	?	?	24	"	

Family MIERSIIDÆ.

Acanthephyra cristata, sp. nov.

Differs from *A. debilis* A. M. Edw. (= *A. gracilis* Smith) in having a much shorter and fewer-spined rostrum, two pairs of longitudinal lateral carinæ on the carapace, a dorsal carina on the fourth abdominal segment, and by the absence of a series of denticles on the posterior margin of the dorsum of the fourth and fifth abdominal segments.

From *A. lanceolata* (*Systellaspis lanceolata* Bate) it also differs by having the rostrum shorter, the lateral and dorsal carinæ of the carapace more prominent, and by the absence of a prominent tooth on the anterior margin of the first abdominal segment.

This species, like *A. debilis* and *A. lanceolata*, has no carina on the dorsal surface of the fifth and sixth abdominal segments.

Length, 78 mm.; rostrum, 13 mm.; carapace, including rostrum, 27.5 mm.

Station	3361.	1471 fathoms.	1 specimen.	
"	3381.	1772 "	1	"

Acanthephyra cucullata, sp. nov.

The integument is soft, membranaceous, and transparent in alcohol. The carapace is carinated in the median dorsal line anteriorly; this carina is furnished with seven minute teeth, and is continued forward to a very small acicular rostrum, which hardly reaches forward to the end of the eyes; the infero-lateral margins of the orbit are continued downward for some distance nearly parallel with one another in a nearly vertical direction, and then suddenly diverge and trend backward, forming the upper wall of the orbit; a sort of hood is thus formed of the anterior part of the carapace, overhanging the facial region. The infra-orbital angle is rounded, not spiniferous. The antennal spine is acute, and advanced forward of the infra-orbital angle. The branchiostegian spine is small and continuous with a longitudinal carina that runs along the branchial region of the carapace. A low fold or ridge marks the upper boundary of the branchial region.

The abdomen is carinated in the median dorsal line on the second to the sixth segment inclusive; the carina is most prominent on the third segment,

where it is produced into a strong posterior tooth which overhangs the anterior part of the fourth segment; the three following segments are furnished with minute posterior teeth. The posterior half of the telson in the unique specimen at hand is missing; there is one pair of minute marginal spines at the hind end of the remaining proximal half. The eyes and eyestalks are well developed, the stalks broadening toward the distal end, and projecting a slender blunt process on the inner side close to the cornea; the eye itself is as broad as the distal end of the peduncle.

The basal segment of the antenna is armed with an acute external spine; the antennal scale is long, gradually narrowing distally to the apex, which is furnished with a small spine.

The thoracic appendages have the form characteristic of the genus *Acanthephyra*, and appear to offer no important specific characters.

Length, 87 mm.; carapace, 27 mm.; antennal scale, 16 mm.

Station 3381. 1772 fathoms. 1 male.

Notostomus fragilis, sp. nov.

Dorsal line of carapace convex and keeled from anterior to posterior margin, anteriorly produced into a short, acute rostrum, which does not exceed the eyestalks in length; the dorsal carina is armed with seven or eight minute teeth on the anterior gastric region and the basal portion of the rostrum; lower margin of rostrum unarmed. A longitudinal carina on each side of the carapace begins near the orbit, above the infra-orbital spine, and runs back to the posterior margin; another carina runs obliquely downward and backward, dividing the branchial from the hepatic regions. The inferior lateral carina is obsolete except for a short distance behind the spine which lies near the anterior margin of the carapace behind the base of the second antenna.

The abdomen is strongly compressed, the third, fourth, fifth, and sixth segments dorsally carinated; the carina terminates in a small tooth at the hind end of the fourth, fifth, and sixth segments; on the fourth segment the carina is divided into two parts by a deep notch about two thirds of the distance from the anterior to the posterior margin of the segment. The telson is channelled on the dorsal side, and is tipped with two long spinous setæ.

The eyestalks taper from the base to the tip; their outer and upper margins are nearly straight, but their inner and lower surfaces are swollen; on the inner side of each stalk, a little way behind the eye, there is a blunt tubercle. The eye itself is small and black. The integument of the eyestalk is transparent, and when held to the light discloses the optic ganglion within, giving off a nerve to the retina and another to the tubercle on the inner side of the stalk.

The basal segment of the antennule is armed with a very small but sharp external spine. The outer side of the second antenna, on the contrary, is unarmed. The antennal scale is very broad, oval, and furnished with a small

spine on the external border, near the distal end. The third maxillipeds are robust; they reach forward far beyond the end of the antennal scales; their terminal segment is triangular in cross section. The first pair of legs are also robust, about equal in length to the third maxillipeds, and their chela is strong, with fingers about equal to the hand in length. The second pair of legs are longer but much weaker than the first pair, the carpus and propodus much elongated, and the fingers not more than a third as long as the hand. The ischium and merus of both the first and the second pair are flattened, and the same compression is seen in the three following pairs of legs, which have the form and proportions characteristic of the genus. The inner branches of the swimmerets are about the length of the telson, while the outer branches are rather longer.

Length, 70 mm.; carapace, 30 mm.; telson, 14 mm.; antennal scale, 11 mm.

Station 3371. 770 fathoms. 1 specimen.

In this specimen the integument is soft and membranaceous, and the carapace is so collapsed that it is difficult to restore its true outline. In several respects this species shows an approach to the genus *Hymenodora*, e. g. the soft integument, small eye, and the reduction of the rostrum.

Notostomus westergreni, sp. nov.

Similar to *N. patentissimus* Bate, with which it agrees in nearly all the details of carinæ, etc., but it differs much from Bate's species in its general form and proportions, the carapace being longer in proportion to its height, and less convex along the dorsal line than it is in *N. patentissimus*. The rostrum, besides, is armed with many more spines (at least twelve) on its inferior margin. Bate says that in *N. patentissimus* the antennal carina terminates in the posterior margin of the carapace, where it is confluent with the lowermost, submarginal carina. This is not the case in *N. westergreni*.

Length, 127 mm.; length of carapace, including rostrum, 61 mm.; height of carapace, 31 mm.

Station 3399. 1740 fathoms. 1 male.

Family PASIPHAEIIDÆ

Pasiphaeia cristata americana, subsp. nov.

This form is closely allied to *P. cristata* Bate, dredged by the "Challenger" in 315 fathoms, near the Fiji Islands. The "Albatross" specimens differ in some respects from the Fiji specimen. They may be considered a geographical race of the same species.

On comparing the two forms it appears that the carapace of the "Albatross" specimens is considerably longer in proportion to the length of the whole body

than it is in the Fiji form, and that the dorsal crest is smaller and somewhat differently shaped. The fifth and sixth abdominal segments are much shorter in proportion to the length of the telson in the former. The antennulary peduncle is only one third as long as the carapace, while in the typical *P. cristata* it is about one half as long as the carapace. Furthermore, the flagellum of the antenna in the former is longer than the body, whereas in the latter it is described as being only one half as long.

Length 65 mm.; carapace, 22 mm.; telson, 7.5 mm.

Station	3385.	286 fathoms.		4 specimens.	
"	3396.	259	"	2	"
"	3403.	384	"	2	"
"	3406.	551	"	3	"

Pasiphaeia magna, sp. nov.

This species is second only to *P. princeps* Smith in dimensions. It is most similar to *P. tarda* Kröyer, from the North Atlantic. Differs from the latter species by having the dorsal line of the carapace more convex, the posterior part of the carapace higher in proportion to the anterior part, the dorsal keel of the carapace rounded except on the anterior gastric region, and the anterior rostrum-like tooth longer and differently shaped. The proportional length of the segments of the third pair of legs appears to be quite different in the two species: in *P. tarda*, according to Kröyer, the propodus and dactylus are of equal length and four times as long as the carpus, while in *P. magna* the dactylus is even shorter than the carpus, which is itself only one sixth as long as the propodus. In *P. tarda*, following Kröyer, the lower margin of the second segment of the second pair of legs is furnished with three spines; in *P. magna* this margin is unarmed but for the tooth at its distal end.

Length, 145 mm.; carapace, including the anterior dorsal tooth, 55 mm.

Station 3384. 458 fathoms. 1 specimen.

Family PENEIDÆ.

Sicyonia affinis, sp. nov.

This species is the Pacific coast representative of *Sicyonia edwardsii*[1] of the Atlantic coast of America. It agrees with *S. edwardsii* in the form and dentition of the carapace, but differs in the form and sculpture of the abdominal segments. In *S. edwardsii* the first four abdominal segments are rugose, and ornamented on the sides with two deeply impressed transverse lines, followed by another less deeply incised near the hind margin of each segment; moreover the pleuræ of these segments are angulated below. In *S. affinis* these

[1] *Sicyonia edwardsii* Miers, Ann. Mag. Nat. Hist., 5th series, VIII. 367, 1881; *Sicyonia carinata* (Olivier) Milne Edwards, Ann. Sci. Nat., XIX. 344–346, Plate IX. Fig. 9, 1830; nec *Sicyonia carinata* (Olivi).

segments are smooth, the impressed lines are absent with the exception of the hinder one of the deeply cut pair, and the pleuræ are broadly rounded below; the peduncle of the second antenna is not much over one half the length of the antennal scale, and the whole appendage is but little longer than the carapace.

Length, 62 mm.; carapace, 20 mm.

Station	3367.	100 fathoms.		1 male, 1 female.
"	3369.	52	"	1 male.
"	3378.	112	"	2 females.
"	3379.	52	"	1 female.

The color in life, as shown in a sketch made by Mr. Westergren, is light greenish yellow, banded with vermilion on the branchial regions and abdomen. Appendages red, antennary flagellum transversely banded with light and dark. The coloration is quite different from that of *S. edwardsii* as given by Dana (Crust. U. S. Explor. Exped., p. 602).

Sicyonia picta, sp. nov.

Rostrum a little shorter than the eyestalks, laterally compressed, elevated, armed with six teeth, three superior, three terminal; inferior margin ciliated. Carapace carinate in the median dorsal line; the carina is furnished with two teeth, one minute, on the anterior part of the gastric region at the base of the rostrum, the other larger, over the cardiac region. An infra-orbital and an hepatic spine are present. General surface of carapace punctate and sparsely clothed with setæ. Abdominal segments smooth, with a median dorsal carina which rises into a strong tooth on the first segment directed upward and forward; on the fifth and sixth segments the carina is drawn out into an acute tooth which is directed horizontally backward. The pleuræ of the abdominal segments are margined and armed with a tooth on the lower border; on the second, third, and fourth segments the tooth is hamate, being directed outward and backward. The general surface of the abdomen is smooth, with a transverse groove on each side of the segments. The telson is channelled above, acute at the tip, and armed with a pair of small lateral spines near the distal end. The eyes are very large, horizontally flattened. Basal segment of antennule armed with two spines on its exterior border; flagella shorter than the peduncle. The peduncle of the second antenna reaches about two thirds of the way to the end of the scale; the flagellum is about equal to the abdomen in length; the basal segment of the peduncle is furnished with a long and acute external spine. The sternum is armed with a long spine between the bases of the second, third, and fourth pairs of legs, as is usual in species of this genus. The last pair of abdominal appendages are a little shorter than the telson.

Length, 70 mm.; carapace, 24 mm.

Station	3355.	182 fathoms.		1 male.
"	3387.	127	"	6 males, 4 females.

On the hinder part of each branchial region there is a dark (in alcohol) ring of pigment. *S. ocellata* Stimpson and *S. penicillata* Lockington are similarly ornamented. The flagellum of the antenna is banded alternately with light and dark color, and there are traces of color on the margins of the rostrum, the dorsal carinæ, and appendages.

Peneus balboæ, sp. nov.

Integument thin and membranaceous, its surface thickly beset with minute squamiform tubercles. The rostrum of the sole specimen procured is broken off a little short of the anterior end of the eye; on the upper margin of the part remaining, and on the median line of the gastric region there is a series of eight slender acute teeth, three of which lie behind the orbit. Rostrum continuous posteriorly with a sharp, non-sulcated carina which becomes obsolete before reaching the posterior margin. Suborbital angle prominent, but not armed with a spine; a small branchiostegian spine projects from the margin on a level with the second antenna. Neither the cervical nor any other grooves are apparent on the carapace. A faint longitudinal ridge runs along the side of the carapace on a level with the orbit; this carina is most conspicuous on the gastric region. Another longitudinal ridge runs from the suborbital angle, dividing into two branches near the middle of the carapace. A third ridge extends from the branchiostegian spine to the lower branch of the ridge last noted. Fourth, fifth, and sixth abdominal segments dorsally carinated, the sixth armed with a small horizontal spine. The fourth, fifth, and sixth segments are also ornamented with a lateral ridge. Eyestalks short; eyes large, globular, black.

Length, 93 mm.; carapace, exclusive of rostrum, 29.5 mm.

Station 3371. 770 fathoms. 1 female.

Solenocera agassizii, sp. nov.

Similar to *S. siphonocera* (Philippi), but different from that species in having the two antennulary flagella much shorter and subequal, and a larger number of teeth on the upper margin of the rostrum and gastric region. Comparison of a specimen fifty-seven millimeters long with *S. siphonocera* of equal size from the Bay of Naples shows that in the former the antennulary flagella are but four fifths the length of the carapace, and that there are eight teeth on the rostrum and gastric region, while in the Neapolitan specimen the antennulary flagella are as long as the distance from the tip of the rostrum to the middle of the third abdominal segment (two fifths longer than the carapace), and there are but six teeth on the rostrum and gastric region. Moreover, not only is the upper flagellum broader (1 m.) and blunter in *S. agassizii* than in *S. siphonocera* (where it is only ½ m. in breadth), but is also subequal in breadth to the lower flagellum, while in the Mediterranean species the upper flagellum is conspicuously narrower than the lower one.

In full-grown specimens of *S. agassizii*, which attain a length of 150 mm., the antennulary flagella are only one half as long as the carapace, or even less. The flagellum of the second antenna is very slender and enormously long, — more than two and two thirds times the length of the whole body. The number of teeth on the rostrum and gastric region is nine.

Length of an adult female, 149 mm.; carapace with rostrum, 54 mm.; rostrum, 13.5 mm.; second antenna, 410 mm.

Station 3389. 210 fathoms. 2 males, 8 females.
" 3391. 153 " 5 males, 6 females.

A *Solenocera* has been recently recorded from the Bay of Bengal by Mr. J. Wood-Mason.[1] In this species the antennulary flagella are described as being shorter and broader than in any previously described species. As no other characters are mentioned, it is impossible to tell whether it is the same as the "Albatross" species. When the remoteness of the localities is considered, it seems hardly warrantable to assume the identity of the East Indian and American species of a comparatively shallow-water genus.

Penaeopsis diomedeae, sp. nov.

Integument hard, firm, and smooth. Rostrum long, nearly horizontal, except near the tip, where it is bent up slightly, acute, armed with four teeth above. A dorsal carina, armed with one tooth on the posterior part of the gastric region, runs the length of the carapace. Cervical groove very deep, but not cutting the dorsal carina. Another deep groove runs backward, and then diagonally upward from the cervical groove toward the posterior border of the carapace, stopping just short of the posterior margin. Antennal region well defined by the cervical groove below and a gastro-antennal groove above. A strong antennal tooth on the margin of carapace, below the orbit, another at the infero-lateral angle, a third just behind the groove that marks the posterior limit of the antennal region, and a fourth on the hinder edge of the cervical groove. Above and behind the last mentioned tooth the cervical groove is indented, and the upper angle of this indentation tends to assume the form of a small tooth or spine.

Fourth, fifth, and sixth abdominal segments carinate on the median dorsal line, and produced to teeth posteriorly. Telson deeply grooved on dorsal side, and armed with a pair of spiniform lateral teeth near the tip. The antennules with their long flagella surpass the whole body in length, the preantenna is oval, [illegible], reaching forward as far as the posterior border of the upper face of the rostrum. The exopodis of the second maxillipeds are very small, not [illegible] than the short [illegible] segment of the limb. Upon the appendages [illegible] of [illegible] exopodites are reduced to the merest rudiments, distinguishable only by the [illegible] Epipodites [illegible], indeed, the exopodites of the posterior appendages [illegible]

[1] [illegible] Wood-Mason, Ann. Mag. Nat. Hist. 6th ser., VII, 188[illegible] 1891.

Length, 215 mm.; carapace, 101 mm.; rostrum, 42 mm.; antennal scale, 33 mm.; telson, 33 mm.

Station	3353.	695	fathoms.	2 females.
"	3358.	555	"	1 male.
"	3384.	458	"	3 females.
"	3393.	1020	"	3 females.
"	3394.	511	"	3 males, 1 female.
"	3395.	730	"	1 male, 1 female.

Haliporus nereus, sp. nov.

Integument membranaceous. Carapace lightly granulated. Rostrum about one third the length of the rest of the carapace, horizontal, armed with six teeth above, ciliated below. Median dorsal line of carapace carinate, with two teeth on the posterior half of the gastric region. The antennal, branchiostegian, and hepatic spines are present, besides one behind the branchiostegian, and another still farther back on the hind border of the cervical groove. Orbital region definitively bounded by an hepatic and a gastro-hepatic sulcus. The hindmost of the lateral spines of the carapace lies in the anterior angle of a triangular field enclosed by branches of the cervical groove; from the infero-posterior angle of this triangle two carinæ run backward along the branchial area; the upper one ends at the postero-lateral margin of the carapace, the lower one meets the inferior submarginal carina of the branchial area before attaining the posterior border. These two carinæ, with the submarginal ridge of the carapace, enclose a long oval area on each branchial region. Third to sixth abdominal segments carinated; on the sixth segment the carina ends in a small tooth. Eyestalks about one half the length of the rostrum; eyes large, black, much broader than their stalks.

In the female there is a large process, covered with stiff hairs, and flattened on the inner side, developed from the base of the third pair of legs. Behind this process lies a pair of flat, setiferous sternal processes. Between the legs of the fourth pair there hangs in the median line a nearly vertical curtain-like partition, notched on the free lower margin, and flanked by two lower blunt setiferous tubercles. The sternum of the posterior thoracic segment has a slightly elevated median longitudinal ridge, and a low transverse ridge at the posterior boundary of the segment.

Length, 81 mm.; carapace, 31 mm.; rostrum, 8 mm.

Station	3353.	695	fathoms.	1 female.
"	3366.	1067	"	1 female.
"	3382.	1793	"	2 females.
"	3398.	1573	"	2 females.
"	3399.	1740	"	1 male.
"	3400.	1322	"	2 females.
"	3407.	885	"	1 female.
"	3413.	1360	"	1 male, 2 females.

Haliporus doris, sp. nov.

A larger and more robust species than *H. nereus*, with a stronger upward curve to the rostrum. The tubercular processes of the third pair of legs, together with the sternal tubercles immediately behind them, are very like the corresponding structures in *H. nereus*. But here the likeness between the sexual parts of the females of the two species ends. Betwixt the legs of the fourth pair there is a transverse diaphragm consisting of a median tongue, concave on its front face, its lower edge entire, supported on each side by a strong blunt triangular process, of equal height with the median tongue-like plate. Between the bases of the fifth pair of legs, in place of the low longitudinal ridge seen in *H. nereus*, there is, in this species, a large setiferous trigonal tooth, acute at the tip, equalling in height the transverse partition on the sternum of the antecedent segment. The posterior median angle of this tooth abuts against the low transverse ridge that forms the posterior limit of the last thoracic sternum.

Length, 104 mm.; rostrum, 10 mm.; whole carapace, 42 mm.

Station 3414. 2232 fathoms. 4 females.
" 3415. 1879 " 1 female.

Haliporus thetis, sp. nov.

Integument membranaceous. Rostrum rather less than one third as long as the rest of the carapace, curved strongly upward, upper margin convex, armed with five teeth. A distinct carina, bearing three teeth, runs the length of the median line of the gastric area, from the base of the rostrum to the cervical groove. Back of the cervical groove this carina continues on as a low blunt ridge to the posterior border of the carapace. Posteriorly, this ridge gives off two pairs of lateral branches, which course diagonally backward to the posterior margin of the carapace, marking off two triangular fields on the cardiac region, one enclosed within the other. The spinous armature of the carapace consists of an antennal, a very small branchiostegal, an hepatic, and a lateral spine on the posterior edge of the cervical groove. The spine which lies a little way behind the branchiostegian spine in *H. nereus* and *H. doris* is lacking in this species. Antennal and orbital regions well defined. All the segments of the abdomen are carinate along their median dorsal line. The pleurae are shallow and rounded. A longitudinal furrow on each side of the abdominal segments. Eye-stalks one half the length of the rostrum; eyes large, black, broader than their stalks.

Length, 94 mm.; rostrum, 9 mm.; carapace, including rostrum, 33 mm.

Station 3413. 1360 fathoms. 1 female.

Aristæus occidentalis, sp. nov.

Similar to *A. antennatus* (Risso) of the Mediterranean Sea. By comparison with Duvernoy's figures of *A. antennatus* it appears that the Pacific species has a longer, more strongly upturned rostrum, and that it differs furthermore in having the sixth abdominal segment carinated and toothed, and in having much longer abdominal appendages. As in *A. antennatus*, there is no epipod on either the last or the next to the last pair of legs.

Length, 158 mm.; rostrum, 49 mm. carapace, including rostrum, 85 mm.

Station 3403. 384 fathoms. 1 male.
" 3410. 331 " 2 females.

Hemipeneus triton, sp. nov

This species, like *H. spinidorsalis* Bate, is remarkable for the long, curved thorn on the dorsal side of the third abdominal segment. It differs from *H. spinidorsalis* in having a much shorter rostrum, and longer, more flattened outer antennulary flagella. The rostrum is shorter than in any previously described species, being much shorter than the eyestalks; it is furnished with from two to four teeth above. The sixth abdominal somite is longer than in *H. spinidorsalis*. Another difference between the two species affects the inner branch of the second abdominal appendages of the male; in both species this branch is triple; in *H. spinidorsalis* the anterior piece is a horny plate, concave within and furnished with setæ on its distal border; the middle piece has the form of a long triangular tooth, shorter than the anterior plate; the posterior piece is a longer multiarticulate flagellum, homologous with the inner branch of the following pairs of appendages. In *H. triton*, the middle tooth-like process is developed into a broad plate which exceeds in length the anterior plate.

Length, 127 mm.; carapace, 44.5 mm.; rostrum, 6 mm.

Station 3360. 1672 fathoms. 1 female.
" 3374. 1823 " 1 male, 5 females.
" 3381. 1772 " 3 males, 1 female.

Benthesicymus tanneri, sp. nov.

In this species the carina on the fifth and sixth abdominal segments terminates posteriorly in a small acute tooth, whereas in *B. altus* Bate these segments are devoid of teeth, the posterior margin rising to form a peculiar transverse ridge. *B. brasiliensis* Bate differs from *B. tanneri* in having the carapace higher, with more convex infero-lateral borders, the third, fourth, and fifth abdominal segments toothed, the sixth toothless, and in the absence of the tooth or tubercle on the sternum between the abdominal appendages of the

first pair. *B. bartletti* Smith, from the Atlantic side of the continent, resembles *B. tanneri* in many respects, but is distinguishable at a glance by the long spine on the dorsum of the fifth abdominal segment. *B. moratus* Smith, another allied species, differs in having a distinct hepatic spine, a much broader merus joint to the second maxilliped, in the presence of small exopods at the bases of all the thoracic appendages, etc.

Color in life, deep red, with a large patch of bright blue on the back of the second, third, and fourth abdominal segments; eyes black.

Length, 112 mm.; carapace 44.5 mm.; rostrum, 8 mm.

Station	3358.	555	fathoms.	3 males, 2 females.
"	3362.	1175	"	1 male, 1 female.
"	3363.	978	"	3 males, 5 females.
"	3364.	902	"	2 males.
"	3365.	1010	"	1 female.
"	3366.	1067	"	1 male, 1 female.
"	3376.	1132	"	2 females.
"	3377.	764	"	1 male.
"	3380.	899	"	1 male.
"	3384.	458	"	27 males, 36 females.
"	3393.	1020	"	2 males, 3 females.
"	3400.	1322	"	1 female.
"	3403.	384	"	1 male, 1 female.
"	3404.	385	"	1 female.
"	3407.	885	"	5 females.
"	3410.	331	"	2 males, 3 females.
"	3411.	1189	"	1 male, 1 female.
"	3418.	660	"	7 males, 8 females.
"	3424.	676	"	1 male.
"	3425.	680	"	1 male
"	3435.	859	"	3 males, 2 females
"	3436.	905	"	5 females.

Family SERGESTIDÆ

Sergestes inous, sp. nov.

Near *S. mollis* Smith. Besides differences of minor importance, the following structural difference is apparent: in *S. mollis* the posterior pleurobranchia of the antepenultimate thoracic segment is replaced by a small simple lamella, which is concealed beneath the following gill, while in *S. inous* the said pleurobranchia is well developed and uncovered.

Length 113 mm.; carapace, 34.5 mm.

Station 3380. 899 fathoms. 1 female.

Sergestes phorcus, sp. nov.

Carapace devoid of spines; rostrum cristiform, short, subquadrate, the anterior margin produced to a short point in the middle. Second, third, and fourth abdominal segments lightly sulcate in the median dorsal line; sixth somite armed with a minute posterior dorsal spine. Eyestalk shorter than proximal segment of the antennulary peduncle; eye subspherical, much wider than its stalk. First and second segments of the antennulary peduncle of equal length, the third considerably shorter. Thoracic appendages much like those of *S. robustus* Smith.

Length, 65 mm.; carapace, 21 mm.

Station	3382.	1793	fathoms.	1 male.
"	3386.	242	"	1 female.
"	3388.	1168	"	2 females.
"	3401.	395	"	1 female.
"	3437.	628	"	1 female.

Sergestes halia, sp. nov.

A small species, in which the cervical groove is nearly obliterated on the dorsal part of the carapace, and the posterior transverse furrow, which in some species of *Sergestes* forms the front boundary of the cardiac area, is obsolete. A sharp spine near the antero-lateral margin of the carapace, and another on the hepatic area. Rostrum cristiform, tapering to a slender, acute point, which overreaches the eye. A longitudinal ridge runs from the base of the antenna backwards, dividing at the hepatic spine into a superior and an inferior branch; the former forms the upper boundary of the branchial area, the latter courses along the middle of the branchial area and fades out before reaching the posterior border of the carapace. Abdominal segments unarmed.

Length, 29 mm.; carapace, 9.3 mm.

Station 3388. Surface to 400 fathoms (submarine tow-net). 3 males.

Suborder SCHIZOPODA.

Family LOPHOGASTRIDÆ.

Gnathophausia dentata, sp. nov.

In this species a thin triangular crest, produced at the apex to a spine, is found at the base of the rostrum, over the anterior part of the gastric region; a minute denticle near the anterior, and another near the posterior end of the crest. The lower spine of the infero-posterior angle of the carapace is reduced to a mere tooth, obsolete in some specimens. Antennal scale very broad (breadth equal to one half the length.)

Distinguished from *G. gracilis* W.-Suhm by the prominent dentate gastric

crest, the small size, or even absence, of the lower spine of the infero-posterior angle of the carapace, the greater breadth of the antennal scale, etc.

Gnathophausia gracilis, var. *brevispinis* Wood-Mason, agrees with *G. dentata* in the obsolescence of the lower posterior spine, but I infer from Wood-Mason's short description that this variety conforms to the type of *G. gracilis* as regards the gastric teeth, antennal scale, etc.

Length, 60 mm.; carapace, including rostrum and dorsal spine, 33 mm.; rostrum, 14 mm.; dorsal spine, 4 mm.

Station	3361.	1471	fathoms.	1	specimen.
"	3375.	1201	"	1	"
"	3400.	1322	"	1	"
"	3406.	551	"	1	"
"	3411.	1189	"	1	"

Family EUCOPIIDÆ.

Eucopia sculpticauda, sp. nov.

Frontal margin very prominent, forming a three-sided blunt rostrum, which projects between the eyestalks and wholly conceals the subjacent ocular segment. Anterior part of the telson deeply furrowed for a little less than one half its length, the furrow bounded on each side by an elevated, rounded ridge; a low median keel, beginning in the anterior furrow, runs back to the hind end of the telson; a constriction near the hind end divides off a terminal plate, which is broadly rounded at the end, its lateral margin concave; the whole dorsal face of the telson, from the posterior end of the anterior ridges to the terminal plate, is beautifully ornamented with a network of ridges like honeycomb.

Length, 66 mm.; carapace, measured from lower angle of orbit to posterior end of the lateral wings, 23 mm.

Station	2619 Hydr.	1000	fathoms.	1 female juv.
"	3407.	885	"	1 female.
"	3413.	1360	"	1 male.

Family MYSIDÆ.

Petalophthalmus pacificus, sp. nov.

Similar to *P. armiger* W.-Suhm,[1] but different in some particulars. The rostrum is more prominent and triangular; there is a median tooth on the

[1] Amongst the material dredged by the "Blake" in the Atlantic in 1877–78, I find the female of *P. armiger*. It agrees closely with the male, barring the usual sexual differences, viz. the presence of an incubatory pouch, and the simple structure of the caudal lobes; the maxillular palp, carapace, telson, etc., are as in the male. The brood pouch consists of six pairs of incubatory lamellæ. The Schizopod described by Suhm as the female of *P. armiger* is apparently a *Boreomysis*. It may be called *B. mysis suhmi*.

carapace behind the base of the rostrum ; the caudal limbs are simple in the male.

Length, 31 mm.

Station 2637 Hydr. 700 fathoms. 1 male.

SCOLOPHTHALMUS, gen. nov

Carapace rostrate, small, covering only the anterior part of the thorax, leaving the last two thoracic segments exposed. Abdomen slender, cylindrical, sixth segment the longest. Eyestalks transformed to sharp spines, visual elements wanting. Antennular peduncle rather long and robust. Antennal scale elongate, oval ; proximal fourth of outer edge smooth, naked, terminating in an angle which bears a strong seta ; the rest of the outer edge fringed with hairs like the inner edge. Mandibular palpi reaching to about the middle of the antennulary flagellum, terminal segment narrowly oblong. Second maxillæ with inner basal part expanded, three-lobed, terminal segment expanded at distal end, triangular. First maxillipeds without an exopod, but furnished with a well developed epipod. Second maxillipeds of moderate length, subpediform. Legs long and slender, antepenultimate pair reaching forward beyond the base of the antennal scale. Marsupial pouch of the female composed of seven pairs of incubatory lamellæ. Telson large, apex truncate, not incised. Outer plates of the swimmerets (uropods) not divided by a transverse suture.

Scolophthalmus lucifugus, sp. nov.

Frontal margin of carapace produced so as to form an acute rostrum ; anterolateral margins oblique, armed with two spines, one behind the external margin of the antennule, the other at the anterior inferior angle. Cervical sulcus well marked, with a distinct linguiform dorsal area behind it. Posterior lateral wings short and rounded. Abdominal segments smooth and cylindrical, sixth segment nearly as long as the two antecedent segments combined. Telson broad, truncate. Eyes atrophied, their peduncles assuming the form of spines. Antennal peduncles one half as long as the carapace, second and third segments about equal in length, a little longer than the first, the third slenderer than the first and second ; the flagella are equal to or rather longer than the peduncle, and present a uniform structure of small articulations, the basal part of the outer flagellum not being expanded. The antennal scale and mandibular palpi are described in the generic diagnosis ; the antennal scale is equal in length to the antennular flagellum. Abdominal limbs (of the female) simple, increasing in length posteriorly, the fifth pair distinctly two-jointed. Inner branch of uropods slender, lanceolate, surpassing the telson and the outer branch, the latter of which is oval and divided by transverse suture.

Length, 42 mm.

Station 3400. 1322 fathoms. 1 female.

CERATOMYSIS, gen. nov.

Cephalothorax robust. Carapace short (leaving the last two segments of the thorax exposed), spinose; frontal margin truncate, not forming a rostrum, armed at the external angles with a pair of long horn-like spines; a conspicuous notch at the anterior end of the lateral margin serving as an excurrent orifice from the respiratory chamber. Abdomen slender, cylindrical, spinose; sixth segment not much longer than the fifth. Eyes absent, their stalks taking the form of slender styles, whose tips are soft and delicate, perhaps serving as tactile organs. Antennular peduncle rather short; flagella much longer than the peduncle, flattened and fringed with long setæ on their margins. Antennal scale linear, ciliated on both margins. Mandibular palpi reaching beyond the antennular peduncle; terminal segment long oval, margins fringed with long setæ. First maxillipeds devoid of an exopod. Distal segment of second maxillipeds oval, ciliate. Legs long and slender, propodi not segmented. Seven pairs of incubatory lamellæ in the female. Fifth and sixth abdominal limbs elongated in the female. Telson linear, setose on the margin. Both branches of the uropods linear, setose on each margin, subequal, shorter than the telson; outer branch not divided by a transverse suture.

Ceratomysis spinosa, sp. nov.

In front of the cervical groove are three long erect spines in the median line, the foremost of which is on the frontal margin; there is, besides, a spine on each side of the carapace in a transverse line with the middle one of the median row; behind the cervical groove there is one spine in the median line near the posterior margin of the carapace, two on each side of the tongue-shaped dorsal area, and a long row of six on each side, in line with the lateral spines of the gastric area. Abdomen armed with five longitudinal rows of spines (one median, four paired and lateral). Telson very long and narrow, nearly equalling the length of the remaining portion of the abdomen.

Color in life, milk-white.

Length, 36 mm; carapace, 9 mm.

Station 3357. 782 fathoms. 1 female.